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Synthesis Report for the Pacific Asia Regional Energy Security (PARES) Project, Phase 1

A Framework for Energy Security Analysis and Application to a Case Study of Japan

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1. Introduction

1.1. Background and Project Goals

Securing the supply of vital resources has been a preoccupation of human collectives from time immemorial. Since the advent of the modern nation-state, securing supplies of vital resources has increasingly become a cornerstone of national policies. Energy did not emerge as a resource necessitating policy attention until the later part of the 19th century and early part of the 20th century. Today, phenomenal political, economic, and military effort is expended to secure energy resources.

Along with the emergence of energy as an object of national policy-making, there also emerged the concept of "energy security." Since World War II, the term has been used to refer to the ability of nations to secure supplies of fuels, primarily fossil fuels. In particular, energy security has meant securing reliable access to crude oil and petroleum fuels at reasonable prices, and development of capabilities to stave off and weather oil "crises."

The energy policy paradigms of both Japan and the United States in the decades after World War II focused on oil. In the 1970s, the energy policy paradigms of the two countries were similar in that they emphasized energy (oil) security through self-sufficiency, stockpiling, and development of non-fossil fuel alternatives such as nuclear power and renewable energy. In the last twenty years, however, the energy policy strategies of the two countries have diverged. This is due in part to differences in resource endowment. It is also due to differing and changing approaches to energy security. Neither country's energy security strategy, however, has ever been systematically justified—or challenged—especially on the grounds of the full economic, environmental, and security costs of the energy strategies adopted to achieve energy security.

As we enter the 21st century, with increasingly global, diverse, and competitive markets for fuels and the goods and services that fuels help to produce, the concept of energy security needs to be subjected to wide-ranging and intense scrutiny. Old rationales for energy security policies often no longer apply. At the same time, security concerns quite apart from physical supplies of fuel are receiving more attention as potential drivers of energy policies. For example, the security implications of environmental degradation caused by energy use is now seen as a driver of energy policy.

What then does, or should, "energy security" mean in today's world?

The first phase of the PARES Project established an analytical framework that incorporates a comprehensive concept of energy security, and applied the framework thus developed to Japan as an initial country case study. Japan was selected for several reasons. First, as an island nation with relatively few fossil fuel resources, it represents an interesting physical counterpoint to the experience and position of the United States. Second, Japan possesses a very different culture. Third, as one of the major industrial powers, Japan's energy policy decisions have global ramifications. Fourth, Japan continues to be an economic and technological model for other Asian countries. Its vision of energy security has considerable influence on the policies of other governments in the region. This influential role for Japan becomes increasingly important as rapid economic growth in Asia, and particularly in Northeast Asia, continues.

The first (Japanese case study) phase of the PARES Project is intended to lead to follow-on phases. Additional phases will include evaluation of energy security for other countries in the Pacific Asia region (and possibly the region as a whole), as well as further elaboration and refinement of frameworks for energy security analysis.

1.2. Evaluating Energy Security

The overall analytical approach taken by the PARES Project is to:

- Prepare a consensus working definition of “energy security”,
- Develop a multidimensional analytical framework for evaluating energy security,
- Prepare quantitative and qualitative descriptions of two different short-to-medium range energy “paths” for Japan (1995 to 2020),
- Evaluate the energy paths against a suite of energy security criteria using the analytical framework, and
- Review the results for applicability to other countries of the region.

The first step in the PARES Project was to develop a working definition of energy security. Such a definition is presented at the end of Chapter 3 of this report. A working definition of energy security must include several elements. First, it must specify the types of events that society is to be secured against. In the PARES definition routine risks and radical uncertainties are included. “Routine risks” are risks that can be assigned probabilities, and about which we have some notion of potential damage. “Radical uncertainties” are risks to which one cannot reasonably assign a probability, but which could have catastrophic results. Second, the definition must specify the “dimensions” of energy security, including physical fuel supply, economic impacts, technological risks, environmental considerations, social and cultural impacts, and military security implications. Together, the risks and dimensions constitute a general set of criteria that can be used to measure the relative energy security benefits or costs of past, present, and future energy policies. For each dimension of energy security, and for each of the two types of risk, there are “measures”—policies or other steps that policy-makers can take to enhance energy security—that can be taken to move society towards a position of greater security. In this document, our approach is to enumerate in a comprehensive and structured manner the dimensions of energy security, the risks associated with each dimension, and the various measures that can be used to address the risks, then to use the resulting framework to evaluate the positive and negative aspects of alternative energy policies.

Thus, the first two steps in the PARES Project (as defined above) were to develop a definition of energy security and a framework for analyzing whether energy security is achieved by various energy policies. With an initial framework in place, the next step was to develop alternative energy “paths” (with associated policies) to be evaluated. We focused on two energy paths for Japan. The first is a “Business-as-Usual” (BAU) path reflecting recent trends and policies. The second is an “Alternative” path. Each has been designed to produce approximately the same energy services for Japan over the next 25 years. The paths, however, differ on the types of measures employed to achieve energy security. The paths are spelled out in sufficient quantitative and qualitative detail to allow their relative energy security impacts to be evaluated as explicitly as possible.

Using an integrated software tool (LEAP, or Long-range Energy Alternatives Planning[a]), we evaluated the physical (fuel use and pollutant emission) and direct economic (energy system/fuel costs and benefits) impacts of the two energy paths. We then turned to our energy security framework and used the framework to evaluate the energy security implications of the two energy paths. This case study evaluation has in turn suggested areas for further development of the analytical framework.

The resources that we used in framing our analysis and in evaluating energy security policies included the existing literature on energy security and related topics, but relied primarily on analytical approaches developed as a part of PARES. Three existing literatures are generally relevant to the development of a consensus as to what operational concept of "energy security" should underlie energy paradigms. The first, most widely known, but perhaps least rigorous, is the literature on the political factors affecting energy supply[b]. The second focuses on the relative supplier market diversity of fuel types and creating economic or trading interdependence between energy exporters and importers. The third is the methodology developed at the World Bank to analyze the economics of investing in "insurance" against fuel supply cutoff in island states. To augment these literatures, two additional analytical approaches were developed. The first approach is a technique for evaluating the diversity of fuel types and fuel suppliers used by a given country or region. This diversity evaluation approach is described in a paper by Tom Neff prepared for the PARES project[c] (and summarized later in this report). Dr. Neff's approach has been applied in an approximate manner to the two Japan energy paths as a part of the application of the analytical framework. The second approach developed for PARES uses the tools of "multiple attribute" or "trade-off" analysis. This second approach, as elaborated by Hossein Razavi (also summarized later in this report), has been incorporated into the initial analytical framework developed here.

In addition to a review of existing literature, we solicited expert input on the many facets of energy security and factors that affect energy security. The papers in Attachment Sets A to C summarize some of this expert input.

Another approach employed by the Working Group was a directed "scenario" exercise led by Dr. Paul Mlotok of Global Business Network. The exercise began by identifying different "drivers" that will shape the energy sector in the coming years. Using two key drivers—the stability of geopolitics and the rate of deployment of new technologies—the Group worked toward defining an energy policy for Japan that would be robust under very different year-2020 "end-states". This exercise helped develop an appreciation for the various and varying goals and uncertainties faced in developing energy security policy, as well as an appreciation for the many different points of view about "where we are" and "where we are (or should be) going".

A highly prominent and controversial aspect of Japan's energy policy is its nuclear power program. Reprocessing, re-use, and "breeding" of plutonium, in particular, is a lightning rod for visceral and acrimonious debate. The PARES Working Group made a special effort to solicit expert input on nuclear power issues (commissioned papers on nuclear issues are provided in Attachment Set C). The Working Group chose, however, not to make nuclear energy a central focus of study. The

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[a] The LEAP software system, which includes EDB (the Environmental Database), is an energy/environment planning tool developed and distributed by the Stockholm Environment Institute—Boston Center. LEAP and EDB are integrated as a single analytical tool

[b] For example, Kent Calder (1996), <u>Pacific Defense, Arms, Energy, and America's Future in Asia</u>, Morrow, New York, NY, USA.

[c] Papers by Tom Neff and Hossein Razavi can be found in Attachment Set A to this report.

reason is that discussion of energy security in Japan often focuses on nuclear power to the exclusion of other fuels, eclipsing as well discussion of other energy sectors and other potential measures to enhance energy security. The Working Group's shift in focus is further justified by the fact that the electricity sector in general, and nuclear power in particular, constitute only a small slice of the Japanese energy pie. Although the role of nuclear power in Japan's future is certainly an important topic of inquiry, the Working Group started from the assumption that nuclear power in one form or another will be a part of any future energy path or scenario. In particular, we assume approximately equal shares of nuclear power generation under both of our 1995-to-2020 energy paths. Our judgment is that this approach allows a more unobstructed review of non-nuclear energy security options.

1.3. Road Map of Document

The remainder of this document is laid out as follows:

- **Chapter 2** presents a very brief historical overview of Japan's energy policies, and a snapshot of Japan's current energy economy.
- **Chapter 3** describes a conceptual framework for evaluating energy security. It includes a review of alternative definitions of energy security used in Japan and elsewhere, a listing of measures that are available to enhance energy security—and the costs and benefits of those measures, and the PARES Working Group's operational definition of energy security.
- **Chapter 4** focuses on "Environmental Security". Environmental security is an aspect of national, regional, and global security that both has the potential to strongly affect energy policy and is increasingly emerging as a major issue around the world. In Chapter 4 we describe current concepts of environmental security in Japan and elsewhere, and touch upon measures that can be used to address the need to increase environmental security.
- **Chapter 5** presents analytical approaches to the assessment of comprehensive energy security. It includes a listing of some of the problems with measuring energy security, a brief review of some of the existing approaches for energy security analysis, and a presentation of our PARES framework for evaluating energy security.
- **Chapter 6** details the energy supply/demand model developed for Japan. It includes a brief review of the model structure and modeling system, sources for recent-year data, and descriptions of the two different energy paths that we have assembled.
- **Chapter 7** shows the results of our analysis, starting with a comparison of the direct physical and economic results (fuels required, estimated emissions, costs and benefits) for the two energy paths, and continuing with an evaluation of the relative energy security impacts of the two alternatives, a discussion of how variants of the two paths might change the outcome of the analyses, and an exploration of the ramifications of longer-term scenarios for the short- to medium-term path analysis—and vice-versa.
- **Chapter 8** lays out conclusions from the first year of the PARES Project. It includes a summary of what we see as the ramifications of our study for Japanese and Pacific Asia energy policy, as well as suggestions for future work.

- **Attachments** to this volume present background papers submitted by members of the Working Group and other experts, workpapers documenting the assembly and results of the energy path analysis for Japan, and brief biographies of Working Group members.

2. The Historical Background and Significance of Energy Security in Japan

Analysis of energy security and policies designed to promote energy security requires a review of the underlying history and current status of the energy sector . In this Chapter, we provide a brief overview of the history of energy use and energy policy in Japan. We examine the national and international implications of Japanese energy policy, and the forces that will fundamentally shape future Japanese energy policy.

2.1. The History of Energy Use in Japan

Access to resources, and securing resource supplies, is a hallmark of Japanese government policy. It has been a hallmark since the Meiji Restoration of 1868. Energy policy is one aspect of Japan's overall resource policy. As an island nation with limited reserves of fossil fuels, access to petroleum, coal, and other energy resources was one rationale for Japan's colonial expansion in the period before World War II. The pre-war oil boycott of Japan, led by the United States and the United Kingdom, was a major factor inducing Japan to capture, for instance, oil-rich Indonesia (then the Dutch East Indies). Allied Nations response to the capture of Indonesia and other Japanese actions in Southeast Asia, in turn help precipitate Japanese involvement in World War II**.**

After World War II, Japan concentrated on reconstructing its shattered economy. In the energy sector, policy-makers focused on rebuilding, modernizing, and enlarging coal production systems during the period from 1946 through 1955. During this period, coal production more than doubled, increasing from 530 PJ[d] to 1,270 PJ. However, this was still only about 75 percent of production levels during the early 1940s. This did not hamper Japan's recovery because oil began to replace coal. The early 1950s saw a marked increase in oil consumption, reaching about twice pre-war levels by 1955. A significant portion of Japan's hydroelectric capacity was also developed from 1946 to 1995[1]. During the following decade (1955 to 1965), as the Japanese economy worked to become autonomous from the U.S. and other countries that had helped to guide reconstruction, the energy policy focus was on the streamlining of the coal mining industry, with the introduction of the use of oil products in specific industrial sectors. From 1960 to 1965, for example, overall use of coal in the industrial sector declined roughly 10 percent, while petroleum product use in industry increased by nearly a factor of 3.5. At the same time, the share of the nation's total industrial coal used by the iron and steel sector alone rose from 41 percent to 72 percent (that is, most of the coal still used by 1965 was used in the iron and steel industry), underlining the shift from coal to oil in most other industries[e].

From 1965 until the time of the first "oil crisis" in 1973, the Japanese economy expanded rapidly[f]. Total primary energy use increased during this period by nearly three-fold—at an average rate of increase of nearly 12 percent per year. Oil fueled much of the economic expansion in the industrial

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[d] One petajoule (PJ), or 10^{15} joules, equals one million gigajoules (GJ), and is approximately equal to 23.9 thousand tonnes of oil equivalent.

[e] Data from the spreadsheet "GENJAP.XLS", assembled by the International Energy Studies Group at Lawrence Berkeley National Laboratory. Original data were from the International Energy Agency (IEA) OECD Energy Balances.

[f] Some of the discussion in this section has been derived from Yamanouchi, Y, "Institutional Framework for Japan's Energy Security", and Ogawa, Y, "Experiences in Three Oil Crises and Issues of Future Oil Supply Security", in PARES Background Materials, 12/97.

and other sectors, resulting in an overall dependence on oil for 77.4 percent of Japan's total primary energy use.

The energy crisis of October 1973, caused by an oil export embargo by the Arab members of the Organization of Petroleum Exporting Countries (OPEC), resulted in a short-term reduction in oil production and a period of tight supplies. More importantly, oil prices (nominal—that is, not adjusted for inflation) rose by 200 percent within a period of six months, and then gained another 50 percent in the following three months. Japan was shocked to discover that its newly-developed oil dependence was a severe economic liability under the new price regime. Policy response was almost instantaneous. Japan committed itself to:

1) seeking secure supplies of oil and long-term contracts for oil deliveries,
2) diversifying sources of oil supply (especially attempting to obtain more oil from sources outside of the Middle East),
3) building and maintaining private and national oil reserves,
4) introducing substantial use of natural gas,
5) developing nuclear power (the country's first nuclear power plants were inaugurated in the 1970s),
6) developing technology to substitute for oil in key sectors, and
7) instituting a crash program to improve energy efficiency (the vast gains in energy efficiency during the 1970s, particularly in industry, came to symbolize Japan's resilience in the face of adversity).

The 1973 oil crisis, however, was not the only factor triggering changes in Japan's energy policy. During the entire post-war period industrial pollution (energy and non-energy related) skyrocketed. By 1970 Japan was one of the most polluted countries in the world. Beginning in the late 1950s with the infamous Minamata disease tragedy, citizen opposition to industrial pollution began building. It reached a crescendo in the late 1960s and early 1970s. The famous "Pollution Diet" of 1967 passed fourteen pieces of pollution-related legislation. Among these was the Basic Law on Pollution. Following this, the Environment Agency was established in 1971[2]. The citizen rebellion against industrial pollution prefigured, and accelerated, the above-mentioned energy policy changes.

The second energy crisis in 1978 further reinforced the direction of Japanese energy policy. The crisis was precipitated by the Iranian revolution. Reduction in Iranian oil production in 1978 and 1979 could not in the short term be fully compensated for by other oil producers. As result oil prices once again rose, this time roughly doubling in the 18 months following the beginning of the revolution in October 1978. Japanese policy response was to continue to reduce overall dependence on oil. One specific measure was establishing a special "Accounts for Diversification of Electric Resources", which transferred receipts from taxes on electricity to a fund to subsidize nuclear power and other "new" energy resources

This policy of diversification in fuel types, focusing primarily on increased use of natural gas and nuclear power, continued through 1995. Improvement of energy efficiency has also continued to be a focus, but the rate of efficiency improvement has generally declined through the 1980s and early 1990s, to the point where efficiency improvements in many sectors, subsectors, and end-uses have been minimal. In the case of the automobiles, for example, efficiencies have actually declined.. Other energy policies pursued by Japan over the last decade or so include diversifying sources of oil supply (especially attempting to obtain more oil from sources outside of the Middle East), and building and maintaining private and national oil reserves.

The variation of primary energy[g] use in Japan over the period 1960 through 1994 is shown in Figure 2-1[h]. This figure shows the rapid increase in petroleum products use through 1973, the beginnings of natural gas and nuclear power use (mostly) after 1973, and the gradual growth in the use of coal from 1960 (when coal use again reached prewar levels) until the present. Oil use reached a peak in 1979, fell by over 20 percent—as a result of the measures described above—by 1985, and has been gradually increasing since, regaining the 1979 level of consumption as of 1992.

Table 2-1 presents the changes in the structure of primary energy use over the period 1960 to 1995, expressed as percentages of total fuel demand. The structural changes undertaken in the Japanese economy, particularly after the oil crises of 1973 and 1979, are reflected in the relative fuel shares, with total oil use dropping from over 77 percent of total national primary energy use in 1973 to about 56 percent in both 1985 and 1995[i].

Figure 2-2 presents the history of final energy demand (all fuels combined) by consuming sector over the period 1960 to 1994. Notable here is the gradual shift from an energy economy dominated by industry to one in which other sectors—notably the transport and commercial sectors—are playing a much larger role[j].

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[g] "Primary energy use" is distinguished from "final energy use" in that primary energy use includes fuels used for power and heat generation, losses, fuel used in international shipping, and other energy uses not normally counted as fuels consumption by end-users such as industries, residences, and vehicles.

[h] Data for Figure 1-1 were derived from the spreadsheet "GENJAP.XLS", assembled by the International Energy Studies Group at Lawrence Berkeley National Laboratory (LBNL). Original data for GENJAP.XLS were from the International Energy Agency (IEA) OECD Energy Balances. Figures shown are in petajoules (PJ), or 10^{15} joules. One petajoule equals one million gigajoules (GJ), and is approximately equal to 23.9 thousand tonnes of oil equivalent.

[i] Table 2-1 is based on Table 1.1 of the report Energy in Japan, as obtained from the MITI (Ministry of International Trade and Industry) World-wide Web site: http:/www.miti.go.jp/intro-e/a23120e.html. Note that the data as contained in Figure 2-1 yield slightly different fuel shares than those presented in Table 2-1, probably due mostly to the use of different practices for accounting for the fuel equivalent of hydroelectric, nuclear, and geothermal power output.

[j] Source for data same as for Figure 2-1.

FIGURE 2-1: Primary Energy Use by Fuel in Japan, 1960 to 1994

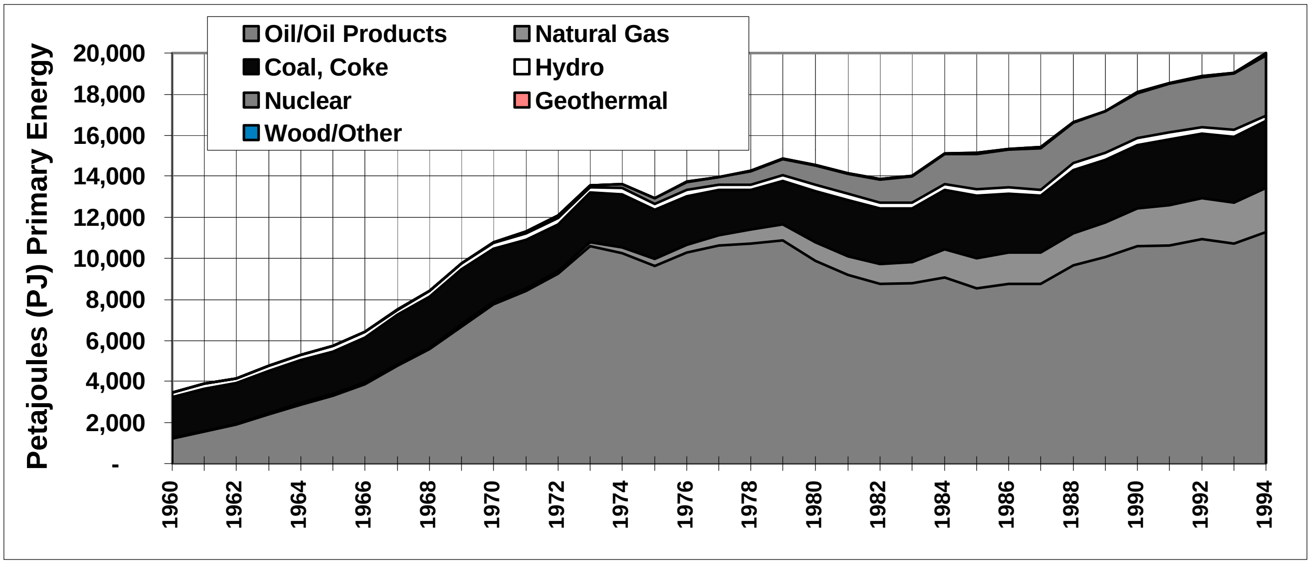
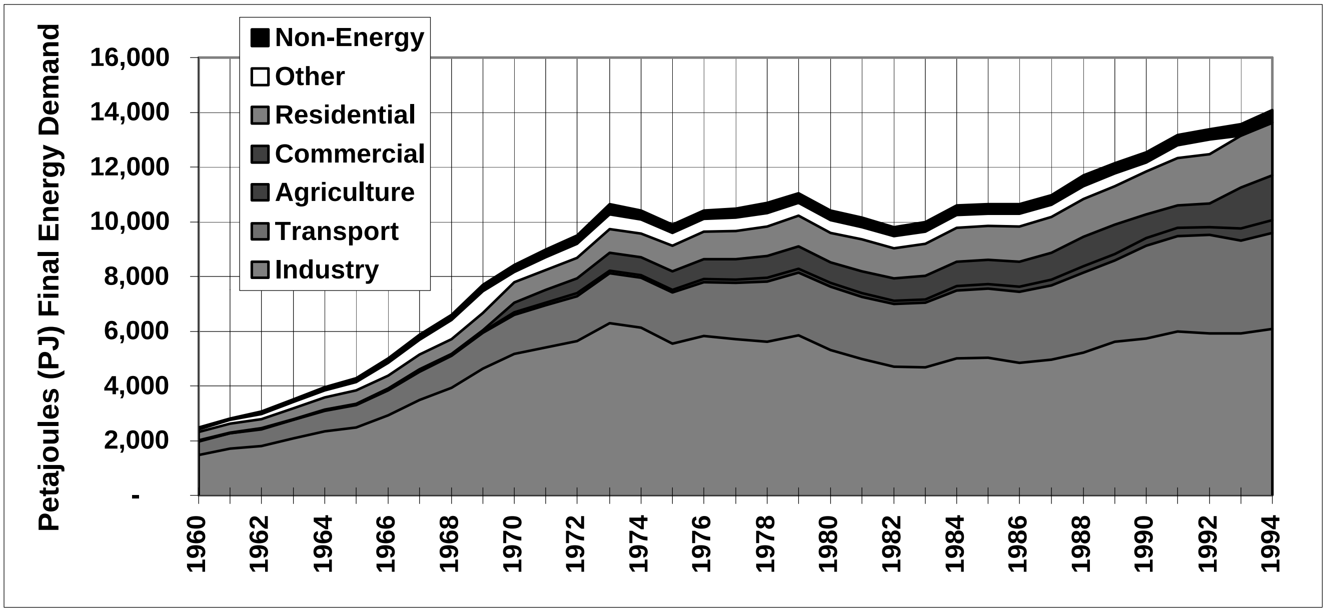


TABLE 2-1: Structure Primary Energy Use by Fuel in Japan, 1960 to 1995
(Percent of total energy use)

	1960	1965	1970	1973	1979	1985	1990	1995
OIL	37.6	59.6	71.9	77.4	71.5	56.3	58.3	55.8
COAL	41.2	27.0	19.9	15.5	13.8	19.4	16.6	16.5
NATURAL GAS	0.9	1.2	1.2	1.5	5.2	9.4	10.1	10.8
NUCLEAR	-	-	0.3	0.6	3.9	8.9	9.4	12.0
HYDRO	15.7	10.6	5.6	4.1	4.6	4.7	4.2	3.5
GEOTHERMAL	-	-	-	-	0.1	0.1	0.1	0.2
NEW ENERGY,etc.	4.6	1.5	1.0	0.9	1.0	1.2	1.3	1.1

FIGURE 2-2: Final Energy Demand by Sector in Japan, 1960 to 1994



2.2. Energy Supply and Demand in Japan as of the Mid-1990s

The current status of the energy sector in Japan forms the backdrop for forward-looking energy policy decisions, and thus for our consideration of the energy security impacts of alternative energy paths. As of 1995, the structure of primary energy demand in Japan was as follows:

- Oil 55.8%
- Coal 16.5%
- Nuclear 12.0%
- Natural Gas 10.8%
- Hydro 3.5%
- Geothermal 0.2%
- Others (including wood and biomass wastes, and solar/wind energy) 1.1%[3].

Virtually all (99.6 percent as of 1993) of the oil used in Japan is imported, and most of Japan's crude oil imports (74.4 percent in 1996[k]) come from the Middle East—principally from Saudi Arabia and the United Arab Emirates[4]. Most of the remainder of Japan's oil imports are from the Asia-Pacific region. Domestic coal production in Japan accounted for about 4.9 percent of total 1994 net coal supplies, and domestic natural gas production accounted for a similar share (3.9 percent) of total gas supplies[5]. Overall, domestic energy resources accounted for 18.5 percent of total primary energy supply in 1994. If nuclear energy production—which primarily uses nuclear fuels imported into Japan—is considered as an imported rather than a domestic energy resource (and this distinction can be argued either way), the contribution of domestic resources to Japan's total primary energy use drops to about 4 percent.

Figure 2-3 presents the division of 1994 final energy use by sector for each of the major fuels and for all fuel use[l]. Almost all of the coal used in Japan (apart from electricity generation) is used in the industrial sector, and three quarters of that is used in the iron and steel industry alone. The transport sector dominates the use of oil products, accounting for slightly less than half of oil products use. The residential and industrial sectors are currently the major end-users of gas, with 42 and 37 percent of demand, respectively. Industry also accounts for 46 percent of electricity use, with the residential and commercial sectors accounting form most of the rest of electricity demand. Overall, 44 percent of total final energy demand in Japan is by the Industrial sector, 26.3 percent by the transport sector, 14.4 percent by the residential sector, 11.9 percent by the commercial sector, and 3.5 percent by the agricultural sector.

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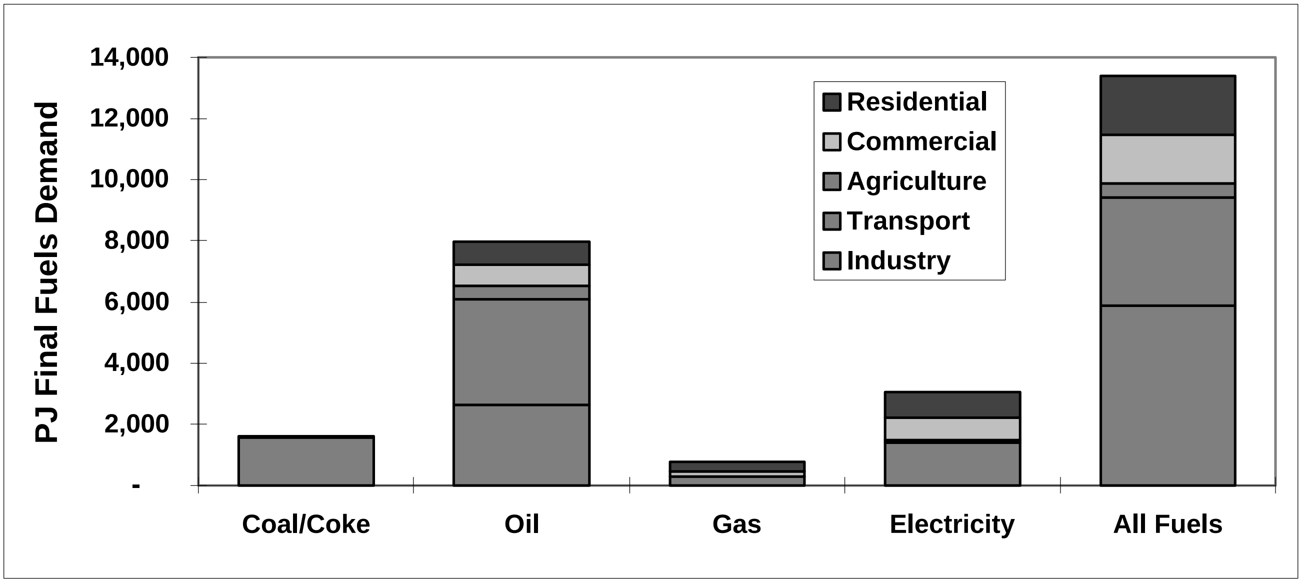
[k] Data from spreadsheet "OILINTER.XLS", "Inter-Area Movements [of oil] 1996", as obtained from the British Petroleum Company (BP) World-wide Web site, www.bpstat.com.

[l] Source for data same as for Figure 2-1.

FIGURE 2-3: Final Energy Demand by Sector and Fuel in Japan, 1995



2.3. Current Energy Policy in Japan

A recent Ministry of International Trade and Industry (MITI) document[6] describes the "underlying goal of Japan's energy policy" as to "attain the 3Es, energy security, economic growth, and environmental protection simultaneously". To achieve this goal, and to "secure a stable supply of energy", Japanese energy policies as stated by MITI include:

- Encouragement of the introduction of alternative energy
- Promotion of energy conservation measures
- Decreasing dependence on petroleum
- Diversification of sources of petroleum away from dependence on the Middle East
- Cooperation with the International Energy Agency (IEA) to stockpile petroleum and prepare for other emergency response measures
- Stabilization of demand for energy
- Securing of supply of non-oil energy sources such as coal, natural gas, and LPG
- Further diversifying the sources of energy supply
- Close cooperation with petroleum-producing countries
- Promotion of natural gas development
- Establishment of coal supply structure
- Promotion of the establishment of nuclear power generation.

These policies have been translated into action through government budgets funded through taxes on electricity, oil products, LNG (liquefied natural gas), LPG (liquefied petroleum gas), electricity, and other fuels. Key elements of Japan's energy security policy funded by these budgets are[m]:

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[m] Some of the discussion in this section has been derived from Yamanouchi, Y, "Institutional Framework for Japan's Energy Security", in PARES Background Materials, 12/97.

- Strategic oil reserves, which as of September 1997 included 85 days of private reserves and 80 days of public reserves funded by the Oil Tax;
- Independent oil supply investigations (prospecting for oil done by non-government groups), including government financing for Japanese oil exploration/mining companies operating in foreign oil fields, augmented by diplomacy to strengthen relations with oil producing nations in the Middle East and elsewhere; and
- Development of nuclear fuel cycle technology, including nuclear fuel recycling and fast breeder reactors, which are funded through "Differential Accounts for Promotion of Electric Resources Development" and other government accounts.

2.4. National Implications of Japan's Energy Policy

Overall, Japan's energy policy in recent years concentrates government support on only a small number of technologies and fuel types, while other supply and demand-side measures receive relatively less attention. Government subsidies for particular technologies and measures seem to have, in some cases, skewed energy-sector development away from more cost-effective options. Relatively high taxes on fuels, coupled with not-fully-competitive markets for many energy commodities, result in high energy prices. These high energy prices act as a drag on Japan's economy, although the extent of this effect is not clear. High energy prices, though, have undoubtedly helped Japan's energy sector become more efficient.

2.5. International Implications of Japan's Energy Policy

One of the key reasons Japan was chosen as the initial case study in the PARES Project is that Japan's energy choices reverberate well beyond its shores. Japan's energy policy, and its approach to energy security, have ramifications for energy policies in other countries. First, Japan is a world leader in research and development in the energy field. Technologies promoted by Japan's energy policies often make their way into the global market. Second, Japan's investments in energy infrastructure at home and abroad—construction of LNG terminals, exploration for oils, development of natural gas pipelines, etc.—have significant effects on energy suppliers and energy markets. Third, Japan's energy choices and industrial practices impact environment outside it borders. Finally and perhaps most importantly, the success of the Japanese economy makes it a model for Asian nations currently in different stages of development. Japan's energy policy choices, and how it defines and pursues energy security in response to global events and challenges, cannot help but have a strong influence on the thinking of leaders in China, the Koreas, Southeast Asia, and elsewhere.

2.6. Implications of Changing Paradigms on Energy Security and Policy in Japan

Japan's energy policy and concepts of energy security are in a state of transition. The changes are being driven by both domestic and international forces, and include the following:

- The general trend toward increasing reliance on markets and private ownership of capital in the global economy
- A stagnant domestic economy
- Nuclear power accidents and related social and political problems in Japan

- Changes in the regulation of and government support for many energy industries, both in Japan and abroad

The global trend toward heavier dependence on markets and market forces is changing Japan's energy policy thinking. Examples of global market trends include the privatization of state utilities, the ownership of power plants by independent (non-utility) business entities, and deregulation in the gas, electric, and other energy industries. National manifestations of these global trends include structural reforms and deregulation of the petroleum products industry starting in 1996, introduction of a system of bidding for independent power production also beginning in 1996, and rate reform in the electric power industry starting in 1995[7].

Domestic forces are also changing Japan's energy policy thinking. Japan's domestic economy has been stagnant through most of the 1990s. As one means to stimulate the economy a package of "structural reforms" is being promoted by Prime Minister Hashimoto to enhance Japan's competitiveness in an era of global "mega-competition". These reforms touch upon all aspects of Japanese society—administration, public finance, social security, the economy, the financial system, and education[8]. If implemented, these "positive" reforms will alter Japanese energy policy. "Negative" events are also changing Japanese energy policy. There has been a recent public backlash against nuclear power in Japan in the wake of the accident at the Monju fast breeder reactor, the revelations of problems in nuclear infrastructure management in the wake of the Monju accident, difficulties in siting new nuclear facilities, and other nuclear-related issues. Overall, the current confluence of international market forces and domestic political and economic changes make a review of the concept of energy security—in general and in Japan in particular—both necessary and timely.

3. The Concept of "Energy Security"

3.1. Three Key Components and Five Principles of Security

The concept of energy security is based on the concept of security in general. It is therefore appropriate to begin a discussion of energy security by clarifying what is meant by the word "security" as it relates to military and non-military policy. Tanaka[n] defines three key questions or components of security policy as follows:

- What to protect?
- What risks to be protected from?
- How to protect?

We can add another important component to the above, namely, "who is protecting whom?" This component of security is not mentioned by Tanaka, but is definitely a subject of discussion in security policy debate. Tanaka also discusses the five principles of security policy which help ensure risk minimization. They can be referred to as "insurance" principles and are as follows:

- *cost sharing*
- *cost minimization*
- *multi-dimensionality, or multi-purposeness*
- *flexibility or switchability*
- *expectation of non-return.*

"Cost sharing" refers to the fact that to ensure risk minimization all beneficiaries need to share the total security costs fairly. This entails clarifying who will get what benefits. Burden sharing often becomes a subject of political discussion and thus clarification of cost/benefits is critically important to define security policy. "Multi-dimensionality or multi-purposeness" refers to the fact that risk minimization should be designed to deal with many types of risks, not just one or two. "Cost minimization" refers to avoidance of over-committing to any one path or insurance policy and that risk minimization should not put an excessive burden on society. "Flexibility or switchability" refers to the fact that circumstances are not constant and as such, a security policy should include built-in flexibility to adjust to external changes. Finally, "expectation of non-return" refers to the fact that although security costs may not generate any visible return, the insurance provided is essential.

Though the above principles offer useful guidelines to the development of security policy, in reality the weight given to any one or combination of the principles varies significantly depending on the nature of three components (what to protect, what risks to protect from, and how to protect) described above. For example, if a particular event or circumstance will have catastrophic results, even if the probability of the event is very uncertain and low, cost minimization as an insurance strategy would be of lower importance. One would be willing to spend more to prevent the risk of such events from being realized. Nuclear deterrence policy is good example of an insurance policy against this type of

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[n] Tanaka, Akihiko. 1997. "Anzen Hosho: Sengo 50 Nen no Mosaku (Secuirty: 50 Years of Trial and Error", Yomiuri Shimbun.

catastrophic risk. On the other hand, if the risks are very uncertain and long-term, types of security measures with multiple purposes may bring some benefits even if the risks turned out not to be real. The so-called "no-regrets policy" taken by the U.S. government on the global climate change issue during the Bush Administration is a good example of this type of approach. If the risks are relatively certain and controllable, the minimum cost principle is more important than the multi-purpose principle. Individual private travel insurance or automobile insurance are good examples of such measures. As a final example, strict application of the above principles may inhibit R&D on advanced energy technologies. Thus, even though the five principles can not be rigidly applied in all cases, they nevertheless provide a useful framework for examining the concept of energy security

3.2. Energy Security: The Conventional View

Numerous papers and books have been written on the concept of energy security, especially at the time of the energy crises in the 1970s and 1980s[o]. Interest was reawakened in 1990-91 in the aftermath of the Gulf War. In the Asia-Pacific area, more attention is currently being paid to the subject due to the rapid increase in energy demand in the region. A review of the literature on energy security, however, demonstrates that the concept is ill-defined, and often is viewed only as a problem of securing oil resources[p].

Why is oil the primary focus of energy security policy? There are good reasons behind this particular focus. First, oil is still the dominant fuel(~40%) in global primary energy supply. Second, the Middle East, where the largest oil reserves exist, is still one of the most unstable areas in the world. Third, and related to the second reason, oil supply and prices are often influenced by political decision of oil suppliers. Fourth, world economic conditions are still vulnerable to oil price volatility, since there are certain key sectors that are heavily dependent on oil (such as transportation, petrochemical, military, etc.) Fifth, the key words here are "volatility" and "instability", although the level of uncertainty in the oil market has been significantly reduced through the process of globalization (for example, through enhanced transparency in pricing and contracting for supplies). In these contexts, oil is certainly the most important fuel to be watched. However, as we will discuss later, it is important to ask similar questions about other important fuels, such as natural gas, coal, and uranium. The relative risks in securing resources of these other fuels seem to be less significant than for oil. Nevertheless, assessments should be made to clarify those "relative security risks" associated with other types of fuel.

Few works have made a serious attempt to clarify the concept of energy security. One attempt at a clear definition of energy security is that of the Working Group on Asian Energy and Security at the Massachusetts Institute of Technology (MIT)'s Center for International Studies. The MIT Working Group defines three distinct goals of energy security[q]:

1. reducing vulnerability to foreign threats or pressure,
2. preventing a supply crisis from occurring, and
3. minimizing the economic and military impact of a supply crisis once it has occurred.

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[o] C.Ebinger ed., "The Critical Link: Energy and National Security in the 1980s," (revised), Ballinger, New York, 1982.

[p] See J. Nickum, "The concept of energy security in Japan", August 29, 1997.

[q] R. Samuels, "Securing Asian Energy Investments," The MIT Japan Program Science, Technology and Management Report, Volume 4, Number 2, September/October 1997.

These goals implicitly assume that an "oil supply crisis" is the central focus of energy security policy. In essence, the central tenets of conventional energy security policy are: 1) reduction of threats to oil supply, and 2) operating in a mode of crisis management. The tenets constitute a shared view among key energy policy-makers in both the East and West, as exemplified by a report recently published by the Trilateral Commission[r].

Analyzing the conventional view of the energy security concept in terms of the three key components of security policy enumerated above, yields the following (see also Table 3-1 below):

What to Protect?

As has already been stated, oil supply is the dominant "what" to be protected in conventional energy security thinking. In developed countries and most developing countries, oil is the dominant fuel in the total primary energy supply picture. It is also the most strategic fuel, in particular for the military sector. Therefore, securing oil is an essential condition for a nation's security and economic welfare. In addition to physical supply, stable oil prices are also a paramount condition and concern for security and economic welfare.

What Risks to be protected from?

Sudden oil supply disruption (which can be caused by a variety of circumstances such as a supplier's embargo, accidents, or bad weather) is the foremost risk to be protected from. Long-term oil resource depletion was once a major consideration, but is currently not at the center of the supply debate. Similar to sudden oil supply disruption, sudden price shock is a critical risk to be protected from. In fact, during the two energy crises in the l970s, physical shortage of oil supply was less important than the price shock. Thus, keeping oil prices stable is a principal component of conventional energy security policy. Price shock and sudden supply disruption is heavily correlated but not 100%. Price shock could happen any time with *expectation* of supply shortage (due to various reasons including political disruption).

How to protect (or prevent)?

Prevention is the best way to minimize the risk. Fostering friendly diplomatic relations with oil supplier countries while at the same time shifting away from heavy dependence on oil are the major policy measures of large oil consuming countries. For example, promotion of nuclear power generation and increased utilization of non-oil fossil fuels (coal and natural gas) are the primary vehicles for reducing oil dependency. Many countries have invested large sums of money in R&D to move away from oil, including investments in alternative energy technologies such as coal liquefaction, coal gasification, and solar thermal power generation. Such R&D programs have met with both success and failure. .Some of the alternative energy sources, such as wind and geothermal, have made commercial success. But success in alternative energy technologies seems to have been heavily dependent on local conditions.

Despite the best efforts to prevent a crisis, one can still occur. In this instance, energy security thinking dictates minimizing the impact of the crisis on national security and economic welfare. Strategic stockpiles, often owned and managed by the government, are one of the most effective ways to deal with a supply disruption crisis and/or price shock. Although stockpiles have not actually been

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[r] Trilateral Commission Report on Energy Security,[need accurate citation] 1996.

used in the case of shortages, they are considered essential to minimize price impact during a crisis situation. Other crisis management measures include both diplomatic and military actions. Although military actions are carried out only as a last resort, the Gulf War is an example of a joint military venture designed to protect oil supply.

Who protects whom?

Although Tanaka does not include this (probably because the answer is clear for military security policy), it is an important question for public policy purposes. Government is certainly an important institution to assure security of general public. In reality, however, each government agency has its own political goal and thus it often creates conflict among government agencies. As a result, the general public is often left out of the security policy debate, and interest groups who have stronger political influence often get the benefit of security policy. Therefore, it is important to answer this question when considering arrangements designed to enhance security.

3.3. Differences in Energy Security Policies

If the above characterization of conventional energy security thinking is shared by the major energy consuming countries, does this mean that there are not any critical differences in energy security policy among them? No. Although many countries share the above broad characteristics, it is also true that there are significant differences. What are the differences and why do they exist? One important factor is, of course, natural and geopolitical conditions. One country might have abundant natural resources and another may not. Some consuming countries are very close to energy-producing countries, and some are far away and thus need transportation of fuel over long distance. Those conditional differences can lead to basic differences in energy security perceptions. In sum, there are three major sources that define the differences in energy security thinking between countries: 1) the degree to which a country is energy resource rich or energy resource poor, 2) the degree to which market forces are allowed to operate as compared to the use of government intervention to set prices, and 3) the degree to which long-term versus short-term planning is employed. Each of these sources of energy security policy differences will be discussed below.

Energy Resource Rich vs. Energy Resource Poor

In the international arena, it is often the case that energy resource rich countries have a greater set of energy security options than energy resource poor countries. And, as a corollary to this greater suite of options, the rich countries are able to emphasize global energy security rather than national energy security. The perception of energy security may significantly differ between those nations that have abundant energy resources and those that do not. Stronger emphases on "national energy security" is clearly more evident for those who don't have abundant resources, with Japan, S. Korea and France serving as key examples. During the 1970s, however, "national energy security" was the dominant subject for energy security policy even for energy rich countries. Energy rich countries are not immune to national security considerations, though, as attested by "Project Independence" initiated by the Nixon Administration immediately following the first oil crisis in 1973. At that time, the goal of energy security policy for most countries was to achieve greater "independence" (that is, reduce oil dependency). Energy resource poor countries like Japan, South Korea, and France were spurred to focus on national energy security because of their increased sense of vulnerability.

The fact that countries, like Japan, whose self sufficiency rate is virtually zero focus on increasing domestic energy sources is not surprising. The heavy dependence on foreign energy sources is one reason that Japan and France have pursued nuclear power development, in particular the nuclear fuel cycle and breeder reactor development. It is often viewed by energy poor countries that energy rich countries have the luxury to ignore nuclear power development or to abandon breeder reactor development.

On the other hand, there is a growing consensus that since the energy market is becoming globalized, any supply shortage or price rise will affect everyone regardless of foreign dependence. According to this view, national energy security concerns lose their grip, and global energy security becomes the primary concern. According to this view, nuclear power and nuclear fuel cycle development can be important even for energy rich countries because such development will contribute to global energy supply stability and resource conservation, rather than contributing to national energy independence. In fact, recent trends in France (shutdown of the Superphoenix reactor) and in Japan (slowing of fast breeder reactor development) suggest that national energy independence is no longer a motive force for nuclear power development. Under the globalized energy market scenario, although there are still significant differences in perception of energy security between energy poor and energy rich countries, the gap in practical energy security measures will narrow.

In addition, it is now increasingly clear that achieving national energy independence is neither practical nor optimal. According to this view, nuclear power and the nuclear fuel cycle can also become important in that the use of nuclear technologies would contribute to global energy supply stability or resource saving, rather than contributing to national energy independence. In fact, recent trends in France (shutdown of Superphoenix) and in Japan (slowing down of FBR development) suggest that national energy independence is no longer a prime goal for nuclear power development even in those countries. Hence, although there are still significant differences in perception of "energy security" between energy poor and energy rich countries, its gap in in terms of the implementation of practical energy security measures is apparently narrowing.

Market vs. Government

Another important source of differences in energy security policy relate to the degree to which market mechanisms or government dictates are employed to handle energy resource transactions. If energy resources are viewed as commodities, it is natural to believe that market mechanisms are the best way to allocate them. However, if energy resources are viewed as "strategic materials", it is natural to consider the role of government as essential to energy policy. In fact, use of the word "security" itself might imply that the role of government is essential. It is commonly agreed that the role of government is critical in crisis management. In non-crisis situations, however, there are distinct differences of opinion on use of market mechanisms or government control. For example, should nuclear power technology and nuclear material be treated as commodities or as strategic materials?

Should government involvement be kept to a minimum so that the market can operate more effectively? Some argue that markets are the best means to allocate energy resources even under in crisis situations. Thus, the argument boils down to a debate on whether energy resources are a commodity or a strategic material. Comparing the U.S. and Japan, the U.S. tends to view energy resources as commodities and Japan tends to view them as strategic materials. The U.S. government, for instance, tends to take a laissez-faire approach toward energy resources, as can be seen with the current steps towards deregulation of the electric utility industry. Also, the U.S. currently provides only minimal support, relatively speaking, to the nuclear power industry. Support for the U.S. nuclear industry is at its lowest level since nuclear power development began in the 1950s. Japan's policy toward nuclear power stands in contrast to that of the U.S. Japan considers nuclear power a pillar of its energy security. There is strong governmental support of the nuclear power industry.

Tax policy offers another contrast in market versus government intervention approaches between Japan and the United States. Japan effectively utilized electricity and imported oil taxes to promote power siting, R&D and secure strategic oil stockpiles[s]. The U.S. tried to introduce an energy tax (a BTU tax) in the early 1990s, but the effort failed. Although introduction of new taxes is always difficult for any government, this may reflect generic differences in attitudes toward the role of government in energy policy in the respective countries.

Another important difference between the countries comes from the view toward market mechanism vs. role of government. If an energy resource is considered a "commodity", it is more natural to believe that market mechanism is the best method for resource allocation. In this case, what would be the role of government in energy security? As described above, there is a shared view that the role of government is critical in crisis management. Under the normal circumstances, the government should (1) prevent "breakdown" in global market, (2) assist private sectors in building long term infrastructure, and (3) prepare contingency plans to reduce impact of market breakdown.

The difference in approach between the countries is more evident when the discussion shifts toward strategic energy material/technology. Some sort of governmental guidance and control is preferred if energy resource is not a regular commodity. Nuclear power technology and nuclear material are a good examples of energy-related products that are not considered regular commodities due to their potentially undesirable alternative uses, such as diversion for use in nuclear weapons. For example, most recently, <u>the </u>United States has warned about agreements for exporting nuclear power to

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[s] Yamanouchi, 1997

the Ukraine, given the recent troubles with Iraq This is an important security dimension of nuclear energy, one that will be discussed in more detail in the next section of this Chapter.

Long-Term vs. Short-Term

A critical source of differences in energy security policy between countries is the time perspective taken. For example, emphasis on crisis management rather than resource depletion may arise from a short-term perspective. Emphasis on market mechanism may also come from a short-term perspective. Countries with longer-term perspectives may emphasize stability over cost effectiveness. These differences will naturally lead to different energy security policies. It is generally viewed that U.S. policy tends to put too much weight on the short term and Japanese policy tends to over-emphasize the long term.

It may not necessarily be the case, however. Long-term thinking may lead a nation to adopt more flexible energy policy, and, conversely, an apparently long-term plan may often have the characteristic of being resistant to change in the short term.   It should be noted, also, that both perspectives are often used to rationalize a particular political objectives (such as cutting federal R&D budgets or supporting projects that are no longer necessary). We believe that there should be a rational balance between long-term and short-term perspectives in energy policy. It is important to distinguish two different kinds of energy security issues. One is “routine risk reduction” and the other is “crisis management”. The former is aiming at building a more robust and resilient energy supply structure, while the latter is aiming at minimizing the impact of crisis given a certain energy supply structure.

Despite the differences in principle as outlined above, however, energy policies in both resource poor countries and resource rich countries are converging as both types of countries recognize the need to face a new paradigm in energy policy.

3.4. Emerging Paradigm: Toward Comprehensive Energy Security

National energy policies in the 1990s are being challenged on multiple fronts. The substance of these challenges needs to be incorporated into a new concept of energy security. Energy policies in the 1990s and beyond have been facing many new challenges that need to be considered as key components of new energy security concepts It is important to note here that energy security policies in various countries are now showing the trend of “convergence” rather than “divergence.” Despite the basic differences in concepts of energy security as discussed above, in reality governments and private sectors are gradually shifting toward more common policy. This convergence does not eliminate regional and national differences, of course, but it is an encouraging sign with regard to minimizing the potential conflict that may come from differences in energy security concepts.

The following is a quick review of the major challenges that will help to bring about a new energy security concept.

Environment

Perhaps the most serious challenge to current energy policy thinking is the need to protect the environment. If environmental problems are to be solved, energy policies will have to be reformulated. International environmental problems present the greatest impetus for change. Two international environmental problems inherently linked with energy consumption, in particular fossil fuel consumption, are acid rain and global climate change[t]. Trans-boundary air pollution (acid rain) is an international issue in Europe, North America, and now East Asia.

Global climate change poses an even broader and more complex challenge to energy policy than trans-boundary air pollution. Although there are relatively simple technical solutions to reduce the emissions of acid rain precursors, including flue gas desulfurization devices, greenhouse gas emissions cannot so easily be abated. As acknowledged by the recent Kyoto Accord, a comprehensive approach toward greenhouse gas emissions is necessary[u]. The climate change issue also brings in a much longer time perspective than business and governments are used to dealing with. Other environmental issues, such as radioactive waste management, also require long-term perspectives. In sum, environmental issues must be incorporated into the energy security concept.

Technology

Risks associated with advanced technologies challenge current energy policy thinking. Conventional thinking understates such risks and tends to see them as short-term, not long-term. Risks include accidents such as those at Three Mile Island in the United States and Chernobyl in the former Soviet Union, or the failure of R&D efforts such as the synthetic fuel, fast breeder reactor, and solar thermal programs in the U.S. Technological risks can be trans-national; the accident at Chernobyl is a good example of an incident with decidedly trans-national implications. Also, markets for advanced technologies are becoming global. Thus, technological risks can be exported. Nuclear technology, for example, is being exported to developing countries. Because we are rapidly moving toward a global "technology intensive" energy society, a new energy security concept must address the various domestic and international risks associated with advanced technologies.

Demand Side Management

Another challenge to energy policy thinking is energy demand itself. Conventional energy policy seeks to assure supply while assuming that demand is given. This notion has been changing since the mid-1980s when the concept of demand side management (DSM) was first incorporated into energy planning. Now, management of energy demand is almost on an equal footing with management of supply. DSM does not, however, eliminate uncertainties that are inherent in energy policy planning. Unexpected demand surges and drops occur depending on, for instance, weather patterns and economic conditions.

There are risks associated with energy demand just as with supply. Conventional energy policy thinking has tended to underestimate demand-side risks. Risks stem from, for example, demand surges (periods of peak demand). These are a serious concern for utility management, but managing peak demand is not easy, particularly given uncertainties in consumer behavior. Long recessions are another major concern for energy industry managers, since recession means large supply capacity surpluses.

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[t] Asuka, Yamaji, 1997

[u] Kawashima, 1993, 1997

Therefore, uncertainty (risk) in the demand side of the total energy picture is a key component of a new concept of energy security.

Social-Cultural Factors

Not in my backyard (NIMBY) and environmental justice concerns are becoming global phenomena, making it increasingly difficult to site "nuisance facilities" such as large power plants, waste treatment and disposal facilities. Although people may recognize the need for such facilities, many communities prefer not to the actual plants in their neighborhood. Opposition to plant siting has elevated the important of local politics in energy policy planning. Who has the right to decide to locate such facilities? Who has the right to refuse? Can any rational policy-making process satisfy all stakeholders? These questions pose not only a challenge to energy security policy, but also to democratic institutions themselves. NIMBY epitomizes the "social and cultural" risks that need to be recognized in policy making agendas. Various social-cultural factors present a challenge to current energy policy thinking.

There are "enviro-economic" concerns as well. It is often the case that the party who bears the risk should get economic compensation. But how much is reasonable and who should be qualified to receive such compensation? These issues are often difficult to decide. In Japan, there are three important laws to promote siting of power plant facilities through compensation mechanisms. These laws seemed to be working very well until mid 1980s, but "just compensation" may no longer be enough for local community as they become more affluent without such compensation.

Public confidence is also a social factor influencing energy policy. In Japan, the recent accident at the site of Japan's experimental fast breeder reactor, MONJU, demonstrated that public confidence can be lost very easily[v]. Once lost, public confidence is hard to recover. "Public confidence" should be distinguished from "public acceptance", which is commonly used in traditional energy policy thinking. Promoting public acceptance is often the object of public relations campaigns. Promoting public confidence involves more than public relations. Examples of efforts to increase public confidence in energy decisions include, for example, recent efforts by the U.S. Department of Energy (DOE) to increase information disclosure, as well as effort by the Japanese governments to make the nuclear policy-making process more transparent (for instance by holding roundtable discussions). Accounting for social-cultural factors and increasing public confidence in energy choices are therefore central components of a new concept of energy security.

International Relations-Military

New dimensions in international relations and new military risks are challenging traditional energy policy-making. The end of the Cold War has brought in its wake a new level of uncertainty in international politics. Although the risk of a world war is drastically reduced, the threat of regional conflicts has increased. One of the areas with the highest potential for regional conflict is the Korean Peninsula. Tensions have increased (due, for example, to the dispute between South Korea and Taiwan over Taiwanese shipment of low level nuclear waste to North Korea) and decreased (due, for example,

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[v] In December 1995, Japan's first prototype Fast Breeder Reactor, called MONJU (280 MWe), had a sodium leak accident. It turned out that the technical implications of the accident were much less significant than the social and political implications, primarily due to the way that PNC (Power Reactor and Nuclear Fuel Development Corporation, operator and owner of MONJU) mishandled the release of information about the accident, and PNC's poor public relation behaviors.

to establishment of the Korean Peninsula Energy Development Organization (KEDO)). KEDO is an excellent illustration of the linking of energy, especially nuclear power, issues and military security issues. The international politics of plutonium fuel cycle development with its associated risks of nuclear terrorism and proliferation remains an area where energy security and military security issues meet. The brave new world of post-Cold War international relations must be accounted for in a new concept of energy security.

The above five key components—environment, technology, demand side management, social and cultural factors, and post-Cold War international relations—are central additions to the traditional supply-side point of view in a new Comprehensive Energy Security Concept.

3.5. History of Energy Security in Japan

Japan was self-sufficient in energy until the early part of the 20th century. It was not until the mid-1960s that import dependence exceeded 50 percent. Import dependence increased in the post-war period as the country shifted its primary energy supply from domestic coal to cheap foreign oil in order to sustain rapid economic growth. By 1973, its import dependence reached more than 90 percent.

After the oil crisis in 1973, the major emphasis of energy policy in Japan was on oil, in particular protecting the oil industry and reducing oil dependence. Memories of the oil embargo during the Pacific War were also still vivid, and public fear of energy shortages led the government to increase its control over the energy industry. In 1974, Japan introduced a series of laws designed to put its energy policy into practice. A special account endowed by new taxes on imported oil and on electricity was created in order to secure funds for oil exploration, oil stockpiling, and development of alternative energy sources such as nuclear power and coal liquefaction. In 1979, after the second oil crisis, another series of laws were introduced to promote non-nuclear energy technologies and energy efficiency improvements. Still, the overall emphasis of Japanese energy policy was on oil.

When oil prices hit low levels in mid-1980s, however, energy policy shifted course slightly. Oil dependence and import dependence was allowed to increase in exchange for short-term economic benefits. The Long Term Energy Perspective, periodically published by a MITI advisory council, was often revised to reflect the new energy situation in which oil supply had become more stable and growth in energy demand had also become somewhat more stable.

Throughout the period of the 1970s and 1980s, Japan’s strong commitment to nuclear energy remained constant. Nuclear energy development, in fact, started before the first oil crisis. The original goal of nuclear energy development was to establish an indigenous nuclear fuel cycle with breeder reactor technology. This, it was felt, would assure energy independence for Japan. By the mid-1980s, however, it was recognized that breeder reactor technology could not be commercialized in the near-term future. Thus, nuclear energy would not assure near-term energy independence for Japan. Nevertheless, nuclear power was, and still is today considered a “quasi-domestic” source, since its fuel supply and price are much more stable than fossil fuel, it is easier to stockpile, and technological development could increase Japan’s self-sufficiency.

During the 1990s, Japan’s energy policy has faced many new challenges. The global climate change issue has created renewed interest in nuclear power and renewable energy technologies. Pressure to reduce energy prices through deregulation has shifted the priority of energy industry from supply security to cost effectiveness. Electricity demand increase, in particular summer peak increase, remains a major supply pressure for utility industry. Energy consumers have lost their incentives and interests to save energy, and Japan's primary energy consumption has been increasing steadily in the last few years while its energy intensity has also been increasing slightly. Domestic politics also changed radically in the 1990s. Local governments have had more political power in key policy decisions on energy policy. After the Monju accident in 1995, Governors of three prefectures where 70% of nuclear power plants exist officially sent a letter to the prime minister to reform nuclear policy and declared not to accept any new projects until "there is a national consensus on nuclear energy policy". Then, in 1996, Maki, a small town in Niigata prefecture, voted via referendum to reject a proposed new nuclear power plant.

Japan's energy policy therefore needs a new set of priorities in achieving its policy goals. Energy security, defined by the conventional concept, may no longer be effective to achieve such goals. A recent paper by a senior MITI official suggests that the priorities of energy security should be instructed by the following perspectives[w]:

Oil and fossil fuel are still dominant in considering world energy security

Geopolitical risks remain important risk that would affect energy supply

Environmental and social issues should be also considered part of "energy security"

More emphasis should be put on "global security"

Transparency of energy market is important

Crisis management and prevention are both important

Common interests and actions among concerned nations are important

The most recent version of MITI's long term energy perspective strongly emphasizes the reduction of global climate change and CO_2 emissions as a major policy goal. The MITI energy prospective reconfirms the importance of nuclear power as a "non-carbon energy" source, and makes a strong commitment to promote renewable energy sources. MITI's policy goal is now so-called "3 E (Energy, Environment, Economy)", and implicitly de-emphasizes the importance of energy security.

This new formulation of MITI's policy goal is consistent with our new concept of energy security, and thus we believe that the following discussion would be useful and pragmatic for Japan's new thinking about energy security.

3.6. General Framework of Comprehensive Energy Security in Japan

Japan's current energy supply structure indicates that the country is still heavily dependent on imported oil, and that total import dependence remains very high (more than 80%). Nuclear power and natural gas have contributed significantly to reduce Japan's oil dependence, in particular in the electricity sector, whose oil dependence is now less than 30%. Oil, however, is still a dominant fuel for

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[w] T. Taniguchi, "Energy Security Issues in the 21st Century," October 1996.

production of petroleum products (chemical industry) and as a fuel for the transportation sector, thus leaving those sectors most vulnerable in terms of oil dependence. The contribution of renewable energy sources to date has been very limited, even when one includes hydro power (whose share of generation has not been increasing). Although the energy intensity (energy consumption per unit GDP) of the Japanese economy remains low by international standards, the energy intensity of the economy has not improved in the last few years.

Given this general background, let us review each type of fuel and its characteristics while identifying energy security implications based on the six key components (Supply, Demand, Environment, Technology, Social-Cultural, and International Relations).

Oil

Oil is still the dominant fuel for Japan's primary energy supply. Although Japan's oil dependence is decreasing, its dependence on the Middle East remains high. Experts suggest, however, that the global oil market has become much more transparent, and this transparency allows for resilience against short term supply crisis[x]. Deregulation of the oil market in Japan has made Japan's domestic oil market more efficient, which has contributed to Japan's economic welfare.

Nevertheless, experts warn that an oil crisis could happen any time in the future. Importance of oil stockpile remains strong, and Japan maintains a healthy stockpile size (120-150 days). The distribution mechanism for the oil stockpile has not, however, been well tested. It would be wise to put more emphasis on crisis management measures such as allocation of fuel, information sharing and distribution within Japan. In addition, particular attention should be paid on the increased traffic of oil transportation in the Asia-Pacific region, as protection of sea lanes can be a common source of concern among East Asian nations.

Experts also seem to agree that the resource depletion issue is not a source of major concern for the short- to mid-term (up to 2020 or so). However, despite large recent investments in oil exploration, Japan's efforts to increase its own domestic oil supply have not been so successful. With Japan's technological capability and large capital, it is not impossible for Japan to be successful for oil exploration. Cooperation with China, Kazahkstan, Russia, etc. would be a wise way to ensure long term oil supply for Japan as well as for the region.

By looking at the demand side, transportation sector and petrochemical industry are the most vulnerable sectors. In this respect, crisis management should focus on these two sectors. For longer term measures, technological developments to reduce oil intensity need to be encouraged. Recent developments of fuel efficient car engines (GDI—gasoline direct injection—oil-electric hybrid engines, and other technologies) are encouraging news. Energy efficiency improvement in the petrochemical industry is also an important area to be looked at as a means to extend oil supplies.

Natural Gas

Natural gas still supplies less than 15% of total primary energy in Japan, but its market fraction is expected to increase in the coming decades due to natural gas' low carbon intensity and its stable supply sources (non-Middle East). However, shifting to natural gas has not helped Japan much in terms of price stability as the prices of gas have been linked to oil price. In addition, natural gas has been

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[x] See Ogawa, Lynch

imported to Japan as a form of Liquefied Natural Gas (LNG), and its market is thus "separated" from the other (pipeline) natural gas market. In this respect, the LNG market is not a global one and thus different approach may be required.

In terms of supply, Japan has been heavily dependent on Indonesia for LNG supply and has begun to diversify its supply sources to other countries such as Qatar. But further diversification may be desirable. Large investment required to establish LNG supply base as well as receiving port may make LNG as a less flexible fuel source. Large asset, once believed to be important to assure long term energy supply, now may lead to less flexibility which in turn may lead to an increased energy security risk. There are two major ways to improve this situation. One is to develop a small scale (modular) LNG technologies, which include the development of small tankers with on-board liquefaction facilities. This type of tanker technology would make LNG as a more flexible fuel source. The other is to invest in natural gas pipeline to link Japanese natural gas market to outside. The latter would require huge investment but is a worthwhile investment considering the importance of natural gas in the coming decades. Again, collaboration with Russia, China, S. Korea etc. would be useful to explore these possibilities. Another important development in natural gas resource is in the Caspian region. Russia, China, the US are all looking at huge gas/oil potential in the region. Japan has also shown its interests in participating in the development of gas/oil. resources. The key strategic question is the pipeline route which could change the geopolitical balance of the region significantly[y]. The future of natural gas resource development and natural gas pipeline planning is one of the most important energy security issues for the coming decades.

Current and future expansion of natural gas use may also depend on the development of gas-related technologies. In particular, the successful development of combined cycle gas turbine (CCGT) is very encouraging. CCGT power plant efficiencies are expected to improve to 50-60% in the coming decades. In fact, the gas turbine itself is one of the most flexible power plant technologies available, since it can use various fuel sources, including natural gas, coal, and biomass. Japan had invested in development of advanced gas turbine technologies in the late 1970s to early '80s, but it is worth while to accelerate these R&D efforts again to develop more advanced gas turbine technologies.

Coal

Coal was once a dominant fuel for Japan, but its share has been constantly declining. However, considering the huge resource base worldwide, Japan's efforts to develop clean coal technologies would be worthwhile long term efforts because the more coal used in the world the lower its dependence on oil and gas. In particular, collaboration with China is critically important in this region to mitigate both acid rain and greenhouse gas emissions. It is most likely that, regardless of availability of alternative energy sources, coal use will expand in the region. Although Japanese government has been supportive to technology transfer of clean coal technologies, more attention should be paid to formulate optimum technology transfer technologies[9]. (Such collaboration may have positive residual effects in terms of supporting cooperation in the aforementioned areas?)

Nuclear Power

Nuclear power's share in power sector has reached more than 35% and is expected to increase its share to 40%. As a base load power source, nuclear power has become an essential power source

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[y] See The Economist, 2/7/98.

for Japan's power sector. Nuclear power has several advantages over other fuels for electricity production. First, its fuel price is relatively stable and its share in total cost is significantly smaller than fossil fueled power source(only 5% or less). Uranium price shock would not result in a sharp increase in nuclear power generation cost. Second, it is resilient against fuel supply interruption. It is easy to stockpile, and once the fuel is loaded there is no need to reload the fuel for about a year. Third, fuel supplier countries are stable and reliable. Fourth, it does not emit any air pollution. And finally, with advanced technologies, resource potential can be expanded.

However, there are sources of concern over future role of nuclear power in enhancing energy security for Japan. First, public confidence in nuclear power is eroding, and the siting of new nuclear power plants is getting more difficult. The problem is its uncertainty involved in plant siting plans. Local politics associated with nuclear power makes energy policy planning more difficult. Democratic policy making process and information disclosure would be essential to improve public confidence in nuclear power, including possible growing use of plebiscite. As noted before, recent efforts taken by both the US and Japanese governments are worth noting. However, it is not clear how those efforts actually lead to improved public confidence in nuclear power. More comprehensive analysis on public confidence and siting issue need to be addressed.

The economics of nuclear power are also uncertain. In particular, uncertainties associated with back end of fuel cycle costs are a major source of concern for power planning. Especially under the pressure of deregulation and competition, nuclear power may lose its economic advantages over fossil fuel. Finally, technological risks involved in nuclear power can be larger than expected. Recent accidents at MONJU and Tokai reprocessing plant have proven the potential vulnerability of nuclear power, especially with closed fuel cycle, as a major energy source. What to do with accumulating spent nuclear fuel is another major policy issue that nuclear utilities are facing now. Some nuclear power plants may face premature shutdown if they cannot find any additional place to store spent fuel. Both Japanese government and nuclear utilities are now planning to build "intermediate spent fuel storage" facility, but again siting of such facility is very difficult.

Development of a plutonium fuel cycle and breeder reactor can be considered as a long-term effort to improve global resource availability, but may not play major roles in the coming decades as originally expected. Besides, the world's surplus of plutonium from both nuclear power and nuclear weapons programs is a major global security concern at present. It would be more prudent for Japan to contribute to reduce global plutonium surplus by "burning" in the conventional LWRs (Pu-thermal), while continuing her long term R&D program to keep this energy option alive for the next generation.

Renewables

Japan's efforts to increase renewable energy supply has not yet been successful. Recent government policy initiatives to provide financial subsidies for home owners may not be sufficient. More innovative thinking is needed to facilitate introduction and diffusion of renewable energy technologies (for example, Green Electricity in Germany and the Netherlands; Prof. Sawa's proposal[10]) The benefits of using renewable energy sources are evident, although their drawbacks need to be recognized as well. There has been public opposition to the development of wind power, geothermal and hydro power plants. No energy technologies can escape from public and social risks: NIMBY can be a common phenomena even for environmentally friendly technologies. Recent deregulation trends will also make it more difficult to introduce expensive renewable energy technologies.

One primary and probably essential way to expand renewable energy sources is to develop more cost-effective energy storage technologies. Development of advanced energy storage technologies deserve further attention. Considering its huge potential, further efforts are needed to promote renewable energy sources.

Energy Efficiency(Demand Side)

Last, but not least, the importance of energy efficiency improvement deserves greater attention. It is generally accepted that energy efficiency in Japan has been much better than most other countries and that there is little potential left for Japan to improve energy efficiency. We believe that this is not necessarily the case. Although both Japan and the U.S. have been improving their energy efficiency constantly during the past 20 years, Japan has been always more energy efficient than the U.S. Recent development of fuel-efficient car engines by Japanese automobile manufactures illustrates Japan's capability and success in energy efficiency technologies. It may be true that the potential for greater energy efficiency differently in Japan as from in the U.S., but there is no technical reason to believe that Japan's energy efficiency cannot be improved further. In the last five years or so, the high energy consumption growth in Japan came primarily from household and commercial sectors as well as transportation sectors. It may be true that it would be more difficult for large industrial customers to improve energy efficiency than other sectors in Japan. Therefore, new approach or strategy may be needed to promote energy efficiency in those high-growth sectors. Improving energy efficiency is certainly the best long term measure to reduce routine risk. Japan, with its leading status in energy efficiency, should contribute to global energy security by transferring its technologies and know-how.

3.7. Possible New Policy Measures to Maximize Japan's Energy Security

Based on the observation of Japanese energy conditions and general framework of comprehensive energy security concept, the following are possible new policy measures that Japan can take to maximize energy security.

Supply

- *Improving supply portfolio: Japan should improve its supply portfolio, in particular its portfolio of oil and other fossil fuel sources. For example, Japan should put more emphasis on front-end ("mountain side") of supply assurance measures, such as direct investment in mine ownership, exploration, distribution (including pipe line) and technology development.*

Japan's energy portfolio (fuel mix, supply source mix etc.) is still not well balanced, although its portfolio for power generation sources has been improved quite significantly. The diversification index measure, as described by Dr. Neff (1997—see Attachment Set A) for this project, is a useful way to look at a country's energy portfolio and its potential vulnerability in the event of an energy crisis. Japan has not been so successful in securing her fuel supply in the front end of natural resources except LNG. One reason for such relative unsuccessfulness is Japanese emphasis on reducing her dependence on natural resources through alternative energy development in particular nuclear power and its fuel cycle technologies. In reality, global dependence on natural resources would remain unchanged for years to come. Lack of emphasis has resulted in relative unfamiliarity and lack of information as well as advanced technologies in this field, which has increased anxiety over future supply.

- *Crisis management measures need to be enhanced, in particular, the protection of sea lanes for transportation of all fossil fuels as well as uranium.*

Japan has sufficient stockpile of oil, but does not have specific stockpile policy for natural gas, coal and uranium. Although relative risks and impacts vary depending on the fuel type and oil is certainly the most vulnerable fuel, more attention should be paid for crisis management for other types of fuel, since few alternative fuel exists now for such applications In the coming decades, transportation of fossil fuels and uranium is estimated to grow substantially in Japan's neighboring sea. Not only for Japan's sake but for all countries in the region, protection of sea lanes is likely to be one of the top priorities of energy security policies.

- *Among different fuel resources, role of natural gas need to be strengthened further in the coming decades. Natural gas supply increase would probably maximize Japan's as well as region's energy security most, considering its supply potential and contribution to better environment.*

As Japan already is moving in the direction, the only thing that needs to be emphasized here would is the confirmation and acceleration of this trend. However, these efforts should be made with parallel efforts in above two measures in the area of natural gas. For example, possible investment in natural gas pipeline or modular LNG technologies need to be considered. Stockpile and diversification of supply should be enhanced, etc.

Demand side

- *Japan's energy efficiency improvement need to be and can be continued. This is the best long term routine risk reduction measure to be considered.*

There is no reason to believe that Japan can continue to improve her energy efficiency beyond the current status. Demand Side Management (DSM) programs need to be expanded and officially integrated into energy policy planning. More economic incentives should be given to improve energy efficiency, as deregulation would put energy prices lower. R&D activities in this field has been primarily facilitated by private efforts, but government can provide more support more. In order to do that, it would be necessary for government policy makers to recognize that energy efficiency improvement is the best strategic measure to improve Japan's energy security. In this sense, it is important to evaluate the proposed new Energy Conservation Law which will introduce tough energy efficiency target for major electric and fuel consuming equipment[z].

- *In particular, the emphasis should be on transportation, commercial and household sectors. They are the most vulnerable sectors to energy crisis and have the largest potential for improvement.*

Energy demand increase in Japan has been primarily driven by the above three sectors. In particular, oil demand has been increasing steadily in the transportation sectors (GDP elasticity has been consistently beyond 1.0-- check with David). As mentioned above, recent technological breakthrough

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[z] The proposed Energy Conservation Law is reportedly more stringent than existing law. It will set the target by "top runner" approach, and penalty will be put on manufacturers if they do not meet the target.

in gasoline engines including hybrid engine is encouraging. This breakthrough has been primarily brought by private sectors. Government support could facilitate these trends further.

Environment

- *Environmental issues have become trans-national issues. Japan should take a regional and global approach to enhance environmental protection and facilitate collaboration and technology transfer in the region.*

It is clear that the major environmental issues that Japan is currently concerned with are mostly trans-national issues. In particular, clean fossil fuel use would be a critical issue for many countries in the region as well as in the world. Japan has technologies and institutional know-how to use fossil fuel cleanly. This know-how should be transferred in a most effective way to the countries that need it. These efforts would surely improve Japan's energy security in return. The emissions reduction target set by the Kyoto Protocol is a difficult goal for Japan to achieve, It would make sense for Japan to aim at global emission reduction while exploring "flexible" approaches to get emissions reduction credit for Japan.

- *For Japan, the tax system should be reorganized to enhance environment protection, rather than reducing oil dependence.*

The current special account tax was designed in the 1970s to improve oil security and facilitate alternative energy development (see the paper by Prof. Yamanouchi in Attachment Set B). While those investment efforts should be continued, at an least equal emphasis should be given to enhancing environment protection. It would be a great opportunity for Japan, if Environmental Agency is upgraded to Ministry of Environment, to reorganize its special account tax system to meet that purpose. Environmental or carbon tax is certainly an important policy option to consider, but careful assessment may be needed to assure the effectiveness and to minimize the negative impact of such taxes.

Society and Culture

- *Public confidence in energy policy making need to be improved in Japan. In order to do that, current trends of opening up the decision making process should be facilitated further.*

Japanese public may have lost their faith in government policy making process, not only in energy but in major economic policy area. In particular, thought, after the MONJU accident, the public confidence in policy making has been eroded completely. It is encouraging to hear that Japanese government has been pushing information disclosure and opening the decision making process by inviting non-experts as well as opponents of government policy in the policy making process. However, it seems those efforts are not enough. Further measures, such as introducing the Information Disclosure Act, would be necessary (e.g. cost information of nuclear power plant is not publicly available yet in Japan) [aa]. Alternative views and policies should be examined more openly so that public can be better informed about their future choice.

[aa] The Information Disclosure Act(draft) has now been approved by the cabinet and will be introduced to the Diet this year.

- *Networking of experts inside Japan beyond various technical fields, as well as outside Japan should be facilitated. These efforts would improve international confidence building, transparency, and credibility of Japanese energy policy.*

Networking among experts of similar field has been strong in Japan, but not among experts of different fields. This lack of networking across fields has been one of the major reasons that policy making process has not been sufficiently transparent. The same thing can be said for networking with experts outside Japan. Expanding such network is essential for confidence building and enhancing transparency of Japanese policy. Lack of such efforts was probably one of the contributing factors to the increased anxiety regarding Japan's plutonium surplus. Given the expected increase in nuclear power capacity in the East Asian region, regional dialogue in nuclear power policy should be facilitated.

Technology

- *Diversification of R&D budget and development efforts need to be facilitated. For public funding programs, more emphasis on generic R&D programs, rather than development (demonstration) programs, is preferred in order to provide various technology options.*

Technological risks, as well as public and political ones, have been underestimated by Japanese policy-makers, and nuclear R&D has been too dominant in energy R&D budget in Japan. Although nuclear energy R&D needs to be continued, a more diversified and balanced approach should be pursued. In addition, large sums of money have been spent on development (demonstration) programs, which tend to narrow down the available technology options. Considering the uncertainties ***<u>and subsequent risks</u>*** of technologies as well as the energy forecasts for the coming decades, more emphasis should be made on generic R&D programs that would create more flexible technology programs.

- *Given deregulation pressure in the energy market, government should provide more incentives to private investment in technology development in the field of energy and environment.*

Deregulation pressure will inevitably reduce private funding for energy and environmental R&D. This is the time for government to act more assertively to provide economic and regulatory incentives to promote private investment in R&D activities. Good example can be found in California ZEV regulation, which have had significant impact on development of clean car engines in Japan. It should be noted here that government role should be limited in providing the incentives or obligations, rather than directing particular technology options. There is also a need to move toward subsidy neutrality among energy choices.

International Relations

- *Japanese policy makers need to be better informed of security and military implications of energy policy. More open discussion on this subject should be encouraged.*

Energy policy has inevitably implications for security and military policies. Political scientists as well as security experts need to be involved more in discussing the international implication of energy policy. In particular, geopolitical consideration of natural resource development, nuclear power and non-proliferation, and role of military actions in crisis management are three major areas that need to be more openly discussed in Japan. There would be cases for Japanese energy policy makers to answer critical international political questions (such as possible Indonesian crisis or Korean conflict and Japan's role in it).

- *As described above, confidence building measures, improving transparency should be a key component of new energy policy of Japan.*

Japan's energy policy, in particular nuclear power policy, has been misinformed or misunderstood by other countries in the past. Instead of defending its policy, Japan should initiate more confidence building measures such as networking, open dialogue, and information disclosure. This has not been a part of energy policy making in Japan, but should be so in the future. This will also make Japan to be better aware of other countries' energy policies. It should be noted that Japanese Atomic Energy Law specifies the three basic principles, independent, democratic and open. It is this open principle that needs to be emphasized more.

3.8. Summary of Alternative Definitions of Energy Security

Table 3-1 provides a synopsis of the "conventional" energy security concept, which stresses stability of oil supplies and oil prices as its primary elements. Table 3-2 shows the evolution of the emphases of policies designed to enhance energy security from a purely supply-centered focus, through the "3 E's" approach now embraced by MITI, to, finally, the focus of the concept of comprehensive energy security that is the topic of this report.

A nation-state is energy secure to the degree that fuel and energy services are available to ensure: a) survival of the nation, b) protection of national welfare, and c) minimization of risks associated with supply and use of fuel and energy services. The dimensions of energy security within each of these three the objectives of energy security which national energy policies must address should be measured, include energy supply-related, economic, technological, environmental, social and cultural, and military/security-related dimensions. *And*, energy policies must address the domestic and international (regional and global) implications of each of these dimensions. Thus, national energy policies should be evaluated against each of the three basic objectives as manifested in the domestic and international implications of each dimension. What distinguishes the PARES energy security definition is its emphasis on the imperative to consider extra-territorial implications of the provision of energy and energy services while recognizing the complexity of actualizing (and measuring) national energy security.

A listing of each dimension of energy security is provided in Table 3-3. Table 3-3 also provides a sampling of the policy issues with which each dimension of energy security is associated. The two right-hand columns of Table 3-3 provide examples, many drawn from the energy security approaches described above, that might be used to address the types of both "routine" and "radical" risk and uncertainty that are faced in the planning, construction, and operation energy systems. The dimensions of energy security listed in Table 3-3 form the basis of the analytical framework for energy security proposed in Chapter 5 of this report, as well as the analysis of candidate energy paths for Japan as described in Chapter 7.

Table 3-1:

The Conventional Energy Security Concept

What to Protect	What Risks to be protected from	How to Protect (Crisis Management)	(Long Term Measures)
Oil Supply	Supply disruption	Stockpile	Diversification
		IEA	Investment in Oil Supply
		Military action	Increase self sufficiency (decrease foreign dependency)
			Diplomacy with suppliers
	Resource depletion		Expand Alternative Energy Sources
Oil Price	Sudden Increase of oil price	Stockpile	Diversification
		Price Control	

Table 3-2:

Evolving Emphases of Energy Security Policies

Conventional	MITI	Alternative Emphases
Supply Security	Energy	Supply
	Economy	Demand Side
	Environment	Environment
		Technology
		Society and Culture
		International Relations-Military

Table 3-3:

ENERGY SECURITY CONCEPTUAL FRAMEWORK

Dimension/Criterion of Risk and Uncertainty Associated with Energy Security	**Energy Security Policy Issues**	**Energy Security Strategies**	
		Reduction and Management of Routine Risk	**Identification and Management of Radical Uncertainty**
1. Energy Supply	• Domestic/Imported • Absolute scarcity • Technology/Fuel Intensive? • Incremental, market friendly, fast, cheap, sustainable?	• Substitute tech. for energy • Efficiency first	• Technological breakthroughs • Exploration and new reserves
2. Economic	• Cost benefit analysis • Risk benefit analysis • Social opportunity cost of supply disruption • Local manufacturing of equipment • Labor • Financing aspects • No regrets	• Compare costs/benefits of insurance strategies to reduce loss-of-supply disruption • Investment to create supplier-consumer inter-dependence • Insurance by fuel (U, oil, gas, coal) stock-piling, quotas global (IEA) or regional (energy charters)	• Export energy intensive industries • Focus on information intensive industries • Export energy or energy technology

Table 3-3 (cont,):

Dimension/Criterion of Risk and Uncertainty Associated with Energy Security	**Energy Security Policy Issues**	**Energy Security Strategies**	
		Reduction and Management of Routine Risk	**Identification and Management of Radical Uncertainty**
3. Technological	• R&D Failure • Technological monoculture vs. Diversification • New materials dependency in technological substitution strategies • Catastrophic failure • Adoption/diffusion or commercialization failure	• Invest in renewables • MOX recycling • Pu/FBR • U from seawater • Spent fuel management issues	• Ultimate Nuclear Waste Storage
4. Environmental	• Local externalities • Regional externalities both atmospheric and maritime • Global externalities • Precautionary Principle	• Risk-benefit analysis and local pollution control • Treaties • Mitigation • Technology transfer	• Thresholds and radical shifts of state such as sea level rise and polar ice melt rate
5. Social-Cultural	• Consensus/conflict in domestic or foreign policy making coalitions • Institutional capacities • Siting and downwind distributional impacts • Populist revulsion or rejection of technocratic strategies • Perceptions and historical lessons	• Transparency • Participation • Accountability • Side Payments • and compensation • Education • Training	

Table 3-3 (cont,):

Dimension/Criterion of Risk and Uncertainty Associated with Energy Security	**Energy Security Policy Issues**	**Energy Security Strategies**	
		Reduction and Management of Routine Risk	**Identification and Management of Radical Uncertainty**
6. Military-Security	• International management of Pu • Proliferation potential • Sea lanes and energy shipping • Geopolitics of oil/gas supplies	• NPT/SG regime • Terrorism and energy facilities • Status • Security alliances • Naval power projection • Transparency and confidence building • Terrorism	• Disposition and disposal of excess nuclear warhead fissile materials • Military options

4. Environmental Security

4.1. Introduction

The intersection of security issues and the environment (or "environmental security" as it is often labeled) is rapidly emerging as a dynamic area of academic research and as an active object of policy-making. There is as yet no agreed upon definition of environmental security. On the contrary, there are a wide diversity of definitions and conceptual orientations depending on the particular point of view used to approach the environment-security linkage. There is even a strong debate as to whether the term should be used at all.

This chapter presents:

1) a brief history of the concept of environmental security,
2) an overview of the various definitions of the term,
3) the definition of environmental security used in this study,
4) a discussion of the relationship between energy security and environmental security, and
5) the PARES Project's work toward incorporating environmental security into a comprehensive energy security concept.

Major literature reviews of the environmental security concept are contained in Renner 1989, Dalby 1992, Bruyninckx 1993, Matthew 1995, Dabelko and Dabelko 1995, Dokken and Graeger 1995, and WWICS 1996 (which contains a comprehensive bibliographic guide to the literature on environmental security). An annotated bibliography is maintained by the Center for Environmental Security at: http://w3.pnl.gov:2080/ces/academic/runci.htm. The above reviews were drawn upon in compiling the information presented below. Given the dynamic nature of the field, the environmental security literature is being added to almost daily.

4.2. History and Present State of the Concept of Environmental Security

The origin of the concept of environmental security is generally dated from a 1977 paper by Lester Brown of the WorldWatch Institute entitled "Redefining National Security".[bb] This paper, however, did not attract significant notice at the time. Richard Ullman was the first international relations scholar to attempt to broaden the concept of national security. In an article published in 1983 entitled "Redefining Security",[cc] Ullman argues that non-military threats to a state need to be included in a new definition of security. Like Brown's paper, Ullman's work went largely unnoticed. They pioneered a rethinking of the traditional security agenda, but their ideas gained little scholarly and even less policy attention.

[bb] Brown 1977.

[cc] Ullman 1983.

The reason for the lack of attention to the early work on environmental security is not difficult to ascertain. At the time, the world was still in the throes of the Cold War, and the imperatives of the Cold War dominated both theory and practice in the security field. As the Cold War was coming to its sudden and unexpected closure, Jessica Tuchman Mathews picked up on the strand of inquiry pioneered by Brown and Ullman, and in a highly influential 1989 article in *Foreign Affairs*, again titled "Redefining Security",[dd] argued that the concept of national security needed to be expanded. She sought a "broadening [of the] definition of national security to include resource, environmental and demographic issues".[ee] Without such a redefinition and accompanying policy changes, she envisioned a grim future of "[h]uman suffering and turmoil".

The end of the Cold War triggered a wholesale reassessment of the concept of national security. Analysis of "unconventional" threats to national security entered the space previously occupied solely by conventional, military threats, and security specialists began to turn their attention to analyzing these unconventional threats—due to technological innovation, the emergence of powerful non-state actors, the expansion of trans-national networks in drug trafficking and terrorism, and environmental degradation, to name a few. A wide-open debate ensued over the meaning of security in the post-Cold War era. One facet of this debate coalesced around the concept of environmental security, which was itself embedded in the larger and rapidly emerging field of inquiry known as environmental politics.

The environmental security concept attracted the first significant attention from policy-makers in the early 1990s. In the United States, the environment came to be associated with security issues at the highest government levels. The connection between the environment and international stability was first formally recognized by former President Bush in the "National Security Strategy of the United States" in 1991. Though the connection had been acknowledged, it was tenuous at best. Two events radically altered this situation. The first was a briefing in 1993 to the National Security Council (NSC) by Thomas Homer-Dixon on the link between environmental degradation and violent conflict, and the second was an article published in the *Atlantic Monthly* by Robert Kaplan on the same theme.

In 1990 Thomas Homer-Dixon, a Canadian international relations specialist, began the first of his projects examining the role of environmental degradation in provoking violent conflict.[ff] As intimated above, his work eventually caught the eye of the national security establishment in the United States. Following the briefing, the NSC's Global Environmental Affairs Directorate and the Department of Defense's Office of Under Secretary of Defense for Environmental Security (which had up to this point focused almost exclusively on cleaning up the military's toxic legacy) began to incorporate into their thinking the notion that violent conflict and the environment were related.

Robert Kaplan picked up on Homer-Dixon's analysis and in the 1994 article mentioned above, entitled "The Coming Anarchy", asserted that environmental degradation was "the national security issue of the early twenty-first century".[gg] Kaplan's sensational image that environmentally-induced chaos and disintegration in the Third World posed serious threats to U.S. interests provoked a gut level response from the security community. The response reached all the way up to the president. President Clinton made the following remarks to the National Academy of Sciences on 19 June 1994:

> "[W]hen you look at the long-run trends that are going on around the world—you read articles like

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[dd] Mathews 1989.

[ee] Mathews 1989:162.

[ff] Homer-Dixon 1991.

[gg] Kaplan 1994:45.

> Robert Kaplan's article in *The Atlantic* [sic] a couple of months ago that some say is too dour…you could visualize a world in which a few million of us live in such opulence we could all be starring in nighttime soaps. And the rest of us look like we're in one of those Mel Gibson "Road Warrior" movies…I was so gripped by many things that were in that article, and by the more academic treatment of the same subject by Professor Homer-Dixon".[hh]

In a landmark speech in April 1996, former Secretary of State Warren Christopher stated that "environmental initiatives" were "low-cost, high-impact tools in promoting our national security". He revealed his intention "to put environmental issues where they belong: in the mainstream of American foreign policy". He outlined the following set of objectives for the State Department: 1) to issue an Annual Report on Global Environmental Challenges designed to assess global trends and establish U.S. priorities, 2) to create six "Environmental Opportunity Hubs" to be housed in U.S. embassies around the world whose function is to assess and address environmental issues worldwide, 3) to convene an International Conference on Treaty Compliance and Enforcement to be hosted by U.S., 4) to establish partnerships with business to tackle environmental problems around the world, and 5) to promote bilateral, regional, and global initiatives related to the environment. Other agencies in U.S. government have since agreed with these principles.[ii]

One year after Christopher's landmark speech Secretary of State Madeleine Albright released the State Department's first Annual Report—*Environmental Diplomacy: The Environment and U.S. Foreign Policy*—which describes current and future State Department activities. The report identifies five global environmental challenges which the U.S. regards as most urgent: climate change, the use of toxic chemicals and pesticides, loss of biological diversity, deforestation, and ocean pollution and over-exploitation. It also establishes five regional-level priorities: water resources, air quality, energy resources, land use, and urban and industrial growth. To help carry out the State Department's environmental diplomacy, six regional environmental hubs are to be established in Costa Rica, Uzbekistan, Ethiopia, Nepal, Jordan, and Thailand.

Present state of the Environmental Security Concept

The above brief history of the concept of environmental security is by no means complete either in terms of content or geographical coverage. It focuses on those aspects of environmental security which have garnered the most attention, and, as far as policy-making initiatives are concerned, focuses exclusively on the United States. The U.S. is currently the most active center of academic scholarship on environmental security, and arguably the most active in promoting environmental security initiatives. Other centers exist in Canada and Europe. Below is a description of the some of the larger centers/projects related to environmental security.

The International Institute for Environmental Strategies and Security (formerly the International Consortium for the Study of Environmental Security) at Laval University in Quebec is one of the earliest centers devoted to the study of environmental security. The Institute started the academic journal *Environment and Security*.

[hh] WWICS 1995:51.

[ii] During the summer of 1996 key officials in the CIA, Department of Defense, Environmental Protection Agency, and Department of Energy signaled their commitment to Christopher's objectives. Also, in August 1996 the Deputy Undersecretary of Defense for Environmental Security described the development of early warning systems and promotion of "military environmental cooperation" as key aspects of former Secretary of Defense William Perry's concept of "preventive defense".

The Project on Environmental Change and Acute Conflict which took place from 1990 to 1993 was the first large-scale project directed by Thomas Homer-Dixon. It found that scarcities of renewable resources—including cropland, forests, water, and fish—are already contributing to violent conflicts in many parts of the developing world, even though these conflicts often appear to be caused solely by political, ethnic, or ideological factors. The project concluded that these conflicts foreshadow a surge of similar violence in coming decades as environmental scarcities worsen in many developing countries. A second project, the Project on Environment, Population and Security took place from 1994 to 1996 and continued to explore the linkages among environment, population, security and governance. Homer-Dixon is currently directly a project on Environmental Scarcity, State Capacity, and Civil Violence[jj].

The Center for Environmental Security[kk] of the Pacific Northwest National Laboratory, which is run by Department of Energy and Department of Defense, was started in 1996. The Center provides a venue for debate and evaluation of environmental issues that impact U.S. national security. In particular, it focuses on issues that address underlying motivations for weapons acquisition, and seeks to develop regional tension-reduction and confidence-building measures relevant to regional environmental problems.

The Environment and Conflicts Project (ENCOP[ll]) is a joint project of the Center for Security Studies and Conflict Research, the Swiss Federal Institute of Technology in Zurich and the Swiss Peace Foundation in Bern. The project, which focused on several regional case studies, lasted from 1992 to 1996. A final report was published in 1996 in three German and/or English volumes.

The Environmental Change and Security Project (ECSP[mm]) of the Woodrow Wilson International Center for Scholars in Washington, DC was started in 1994 and serves as a focal point for a network of experts interested in environmental security ideas. It also serves as an information clearinghouse for environmental security views, activities, and events in both the academic and policy-making worlds. ECSP sponsors regular meetings of an "Environment and Security Discussion Group" and publishes an annual *Environmental Change and Security Project Report*.

Dr. Nils Petter Gleditsch of the Peace Research Institute of Oslo has directed a number of environmental security projects and is editing a volume on environment and conflict.

NATO funded an Advanced Research Workshop on Environmental Security in Norway in 1996 and a Workshop on Social Adaptation to Environmental Change in Austria in 1997. At these workshops NATO countries meet with representatives from Russia and Eastern and Central Europe to discuss environmental and security issues.

Dr. Steve Lonergan of the University of Victoria in British Columbia, Canada is directing the Global Environmental Change and Human Security (GECHS[nn]) Project funded by the International Human Dimensions of Change Project. GECHS's goal is to establish criteria for predicting vulnerability to environmental change, and act as a conduit for interdisciplinary, international research and policy efforts in this area. It has adopted the framework of "human security" (see below) because it not only recognizes the linkages between environment and society, but also acknowledges that our perceptions

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[jj] See http://utl1.library.utoronto.ca/www/pcs/eps.htm for a discussion of all three of Homer-Dixon's projects.

[kk] http://w3.pnl.gov:2080/ces/

[ll] http://www.fsk.ethz.ch/encop/

[mm] http://www.ecsp.si.edu/

[nn] http://steve.geog.uvic.ca/GECHS/index.html

of the environment, and the way we use the environment, are historically, socially and politically constructed.

4.3. Definitions of Environmental Security

The above description of projects gives a sense of the environmental security landscape, but does little to give a sense of the wide range of meanings associated with the concept. By the mid-1990s, the environmental security concept had firmly taken root in the academic and policymaking worlds. However, there exist a tremendous range of definitions and orientations to the term. Fundamentally, they split over the object requiring protecting. These objects include the nation-state, individuals, groups, societies, natural ecosystems, the international system, and the biosphere. Two dominant orientations to environmental security have emerged—one which focuses more on the environment side of the equation (and which is called "human security"), and another which focuses more on the security side (and called "national environmental security"). These will be discussed below along with a third avenue of inquiry which questions the very use of the term "environmental security".

The following categories/perspectives/definitions related to environmental security can be distinguished:[oo]

1) environment affects security
   a) human security
   b) military security

2) security institutions affect environment
   a) negative
   b) positive

3) influence of environmental security ideas
   a) negative
   b) positive.

4.3.1. The Environment Affects Security

How does environmental change affect security issues and institutions?

Human Security. The broadest definition of environmental security is premised on the fact that global and regional environmental degradation and resource scarcity may adversely affect human and/or economic security interests. Thus, the "threat" posed by environmental change is first and foremost a threat to the health and livelihood of all humans on the planet. All humans need to be protected against environmental degradation and resource scarcity. This version of environmental security is often termed "human security". Proponents of this holistic view of security argue for a "redefinition" of security, and tend to emphasize sustainability as the ultimate goal of environmental security. Critics say that such a reading of security renders the term meaningless.

[oo] This categorization scheme follows that developed by Geoffrey Dabelko and P.J. Simmons of the Environmental Change and Security Project.

Advocates of human security include: Brown 1977, Ullman 1983, WCED 1987, Mathews 1989………

Military Security. A more conservative definition of environmental security is premised on the fact that global and regional environmental degradation and resource scarcity may adversely affect traditional military security interests. This view of environmental security holds that environmental change may be a significant contributing factor to political instability and/or violent conflict. This view was popularized by Homer-Dixon (1991, 94,95) and Kaplan.

Homer-Dixon concluded from his Project on Environmental Change and Acute Conflict that violent conflicts in the developing world are being caused or exacerbated by resource scarcities; this form of conflict is likely to increase as adverse environmental change overwhelms the capacity of institutions to adjust and respond, creating conditions for fragmentation or authoritarian government.

Other advocates of this point of view include Gurr 1985, Westing 1986, 1988, 1994, Gleick 1991, 1993. Opponents hold that environment is important only if it contributes to inter-state war, which they argue is unlikely. Those who hold this view include Lipschutz, Lipschutz and Holdren, Deudney.

Frederick (in *Contested Ground*) offers the following definition of environmental security. Environmental security is the "absence of non-conventional threats against the environmental substratum essential to the well-being of [a state's] population and to the maintenance of its functional integrity" [REF]. This is realist perspective; state-centric. This implies preventing or containing specific threats or symptoms of environmental problems to protect more traditional national security interests of a state. Military planners have taken to this definition. They are interested in analyzing environmental factors to anticipate situations in which US military may be called in to intervene.

4.3.2. Security Institutions Affect Environment

A perspective on the environment/security intersection is on how security institutions affect the environment. Security institutions can affect the environment positively or negatively.

Negative. The military adversely affects the environment. Military preparation for armed conflict, the conduct of armed conflict, and the disposal of military waste cause environmental degradation and depletion. "Environmental security" in this perspective means focusing on efforts to clean up military toxics or to reduce the environmental impact of fighting, for example. In 1991 the U.S. Congress funded the Strategic Environmental Research and Development Program (SERDP) with the goals of enhancing environmental compliance, environmental restoration, and environmental data gathering and analysis in the military. The goals of environmental compliance and environmental restoration are central missions of the DOD's Office of the Deputy Undersecretary of Defense for Environmental Security.

DOD's Office of the Deputy Under Secretary of Defense for Environmental Security – goal is compliance and restoration as central missions; the Defense Environmental Restoration Account (DERA). (see Dabelko p 8)

Positive. Security institutions have capabilities which can be put to use in saving the environment; for instance, satellite data. The military has extensive resources and skills that can be applied to domestic and international environmental security issues without compromising its war-fighting capabilities. Environmental security is already a part of military mission of US. Military institutions should be involved in the process of maximizing environmental security. (Butts)

The security community's assets include monitoring and enforcing international environmental agreements; gathering, analyzing, and disseminating scientific data on the natural environment; responding to mitigate environmental crises and disasters; providing technical expertise to other nations' militaries; implementing environmental sustainability programs; guaranteeing access to natural resources; spinning off environmental cleanup technologies; and protecting natural parks and reserves.

Critics say that the military is conflictual and secretive, not cooperative and transparent.

4.3.3. Influence of Environmental Security Ideas

What are the risks of using a vocabulary that, in the arena of world politics, tends to evoke images of war and military action? Some see the environmental security terminology as a positive development and others as a negative development.

<u>Negative</u>. Do not use security rhetoric; military is urgency, zero-sum thinking and fosters a "we versus they" mentality, and language implies likelihood of interstate violence (Deudney). Environmental change is a gradual and long-term process best addressed by building a sense of global solidarity based on shared interests and constructive engagement. Environmental problems are conceptually unlike traditional security problems. Environmental security may be used as an excuse to infringe on sovereignty. Also, it could backfire if the threats posited under environmental security do not pan out. The term will be co-opted by the North; employed to sustain traditional geopolitical security thinking that favor developed states, or promote protection of global e and all of its inhabitants (Dalby). True reason government want to redefine security in e terms is because of parochial bureaucratic interests. Employ term to win attention and funds (Deudney, Levy). Traditional security structures (DOD, DOE, intelligence community) support green missions is classic bureaucratic effort to retain budgets (Finger, Le Prestre)

<u>Positive</u>. The concept of environmental security ideas help foster cooperation (State Department E diplomacy). Framing environment as threat may prompt collective solutions; cooperation if understand shared security interest in protecting the e. Environmental security rhetoric may generate widespread domestic public support, funding, action.

5 trends linking e change to traditional security community (or 5 components of a comprehensive e security policy)

1) Greening the military,

2) Using security assets for e objectives

3) Tracking e factors a sources of conflict

4) After-Impact conflict resolution processes (integrating e issues into conflict resolution processes)

5) Communication and dialogue (the US military serves role in promoting lines of

communication with foreign security communities

4.4. A Definition of Environmental Security

Based on the above discussion of environmental security, it is clear that in the context of an analysis of a single nation's energy security the starting point for most government-level policy analysts will be from a "national security" (versus a "human security") perspective. However, the human security vantage point informs a definition of national environmental security. Thus, the following definition of environmental security is used in the PARES Project:[pp]

Environmental security as it applies to a nation-state is:

1) protection of the health and welfare of its citizens from the impact of environmental change (i.e., securing its citizens against the adverse consequences of environmental change),

2) protection of the economic interests of the nation from the impact of environmental change (i.e., securing its economy against the adverse consequences of environmental change), and

3) mitigation of the impact of environmental change on regions vulnerable to instability and conflict in which the nation and its allies may feel compelled to become involved for strategic or humanitarian reasons (i.e., securing unstable regions against environmental change which may directly or indirectly adversely affect the nation).

Behind the above three conventional security concerns lurks an ethical impulse imparted by the human security school of thinking. The last item above, in particular, implies that a nation's environmental security is dependent on the environmental security of a wider sphere than the territorial boundaries of the nation. The human security and national security split largely turns on the issue of sovereignty. Those who advocate a human security approach tend to question the notion of national sovereignty and those who advocate a national security approach tend to accept the sacredness of sovereignty.

4.5. Environmental Security Research in Japan

The concept of environmental security emerged first in the West. However, it is attracting attention worldwide. Most areas outside the West, though, have been slow in researching the concept, and even slower in incorporating it into environmental and energy related policies.

To the author's knowledge there are no projects in Japan specifically devoted to the study of environmental security. There is a feasibility study at the National Institute for Environmental Studies of the Environment Agency of Japan on global environmental risk management. The project started in 1997 and will bring together researchers from various fields (a Global Risk Research Committee) to develop concepts and analytical frameworks for accessing different types of environmentally-related international threats which a nation-state seeks to avoid. An international symposium, entitled " New Global Environmental Viewpoints: Progress in Global Environmental Risk Research", was held in

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[pp] Definition follows Matthew 1997.

March 1998. This project seems to be the first related to environmental security in Japan.

4.6. Energy Security and Environmental Security

Defining the intersection of environmental security and energy security for a given nation depends on the object of security. The object of security is energy with minimal environmental disruption to the nation. Using the PARES definition of environmental security given above, environmental security can be subsumed within the definition of comprehensive energy security.

Environmental Security Dimensions

Domestic: Energy/environmental security for a nation implies protection of its citizens and economy against the impacts to its domestic environment from energy production, transformation, and use. These impacts can originate from local, national, international, or global environmental problems induced by energy uses. Therefore ensuring environmental security means tackling not only energy-related problems within the nation's territory but also problems outside the territory which impinge on the nation.

International: There are also impacts to the domestic environment of other nations that, while not directly affecting the environment of the nation, may destabilize other nations. For instance, water resource conflicts in Central Asia may affect energy supply from the region which may affect a nation's energy security. Thus, one must specifically analyze 'outside' areas where environmental problems may lead to political instability that will affect a nation's energy security.

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5. Analytical Approaches to the Assessment of Comprehensive Energy Security

5.1. Introduction

In previous chapters of this report we have explored the concept of energy security, both as it has been defined (in a rather narrow sense) in the past, as well as the broader, more comprehensive definition—including environmental security—that we have developed. The drawback, of course, of a broader definition of energy security is that it becomes that much more difficult to evaluate, in a structured and straightforward manner, which policies or sets of policies bring a country (or region) greater energy security (in the broad sense), and which have the opposite effect.

In this chapter we briefly explore the attributes and drawbacks of some of the various tools available for the evaluation of energy security, and put forward an initial framework for the assessment of comprehensive energy security. In so doing, we have tried to be relatively inclusive; that is, we have tried to include a variety of measures and approaches. Nonetheless, we have doubtless fallen short in some areas, and perhaps overemphasized others. It is our hope that the PARES project team and others can work together in subsequent phases of the project to refine and apply the framework presented below. Ultimately, we hope to assemble a transparent, flexible tool (or set of tools) that can be adapted to the evaluation of the energy security impacts of different energy policies, paths, or scenarios in different areas of the world. In Northeast Asia in particular, we hope that international collaborative efforts in evaluating the energy security implications of different paths can lead to robust energy policy approaches that, implemented by individual countries and/or region-wide, can lead to enhanced energy security for all of the countries of the region.

5.2. Problems in Measuring Energy Security

Even when the non-trivial problem of deciding and defining what is meant by "energy security" has been addressed satisfactorily, a host of problems and challenges remain in any attempt to "measure" energy security impacts. These problems and challenges include:

- **Deciding upon a manageable but useful level of detail for the description of energy policies**: In every description of what the future will hold—for the energy sector and otherwise—there is always a dilemma as to how much detail to provide. If too little detail on, for example, an energy path (how the energy sector will evolve from the present into the future) is provided, the description runs the risk of not being credible to policy-makers. On the other hand, providing too much detail can make the modeling of the energy path unwieldy. We suspect that the choice of a level of detail for a given study will need to be carefully informed by consideration of the use to which the energy security study will be put, as well as by cultural considerations.
- **Deciding upon an applicable measure or measures of energy security**: Some studies of energy security may focus on costs and the economy, others on the environment, and others on military security, while still others will try and incorporate some or all of the many aspects of energy security that we propose in this report. Each different approach will suggest a different measure or set of measures to use to judge different policy options. When a number of different measures are used, there is a temptation to aggregate the measures in a single index. Compiling (and interpreting) a

single index that spans qualitatively different measures, however, must be done with the greatest of care to avoid magnifying trivial differences between policies or, on the other hand, obscuring major differences.

- **Incorporating the elements of uncertainty and risk (both routine risk and risk arising from radical uncertainty)**: One thing that can be predicted about the future with some certainty is that it will be not entirely predictable. As a consequence, any analysis of policy options to improve energy security must include a method of somehow evaluating the impacts of uncertainty and risks of various kinds on the energy security outcomes of different energy policy paths.
- **Comparing and weighing tangible and intangible costs and benefits**: There is often the temptation to focus on measures that can be enumerated, thereby ignoring more qualitative considerations that may be of equal or greater importance[qq]. It is therefore a challenge to analysts to devise a way of evaluating the energy security impacts of specific policies that allows due consideration of both quantifiable and non-quantifiable considerations.
- **Addressing and comparing impacts that occur on many different spatial levels and on many different time-scales**: Some of the impacts of a given country's energy policy will occur locally, while others will be regional or global in scope. Similarly, some of the impacts will be felt immediately, while other impacts will take years or decades to have noticeable effects. Another challenge for any method of evaluating energy policies is to provide due consideration to the spatial and temporal distribution of policy impacts.
- **Balancing comprehensiveness with the need for transparency and with other practical considerations**: Given the many aspects of energy security, as we define it here, a balance needs to be struck between comprehensiveness—what policies, impacts, and uncertainties/risks to include, and at what level of detail—and transparency—that is, rendering the analysis sufficiently comprehensible to be deemed trustworthy by policy-makers. In addition, of course, practical considerations such as the time required to prepare an analysis and the cost of the evaluation itself will also be important.

5.3. Existing Analytical Methods and Approaches for Measuring Security Costs and Benefits

To our knowledge, no analytical method for evaluating energy security, in the comprehensive sense we mean it here, has been applied. There are, however, a number of methods (or types of methods) that have been applied to pieces of the energy security puzzle. Some of these methods are reviewed briefly in the paper by Hossein Razavi included in Attachment Set A, and are listed even more briefly below. Another method applicable to particular pieces of the puzzle of energy security analysis—namely to the indexing of the benefits of policies to increase fuel type and fuel supplier diversity—is described in an attached paper by Thomas Neff, and is also summarized briefly below. A more general method, sometimes called multiple attribute analysis, has the potential to incorporate a number of different tools and measures into an overall framework for analysis. A variant of multiple attribute analysis is proposed by Dr. Razavi in his paper, and forms the basis for our draft framework (presented in section 5.4) for the evaluation of energy security impacts of different energy policies.

[qq] This has been described as "confusing the countable with the things that count" (J. Holdren, personal communication, 1981).

5.3.1. Tools used to evaluate selected energy security impacts of energy policies

The energy security impacts of energy policies that are most often evaluated using existing tools are economic impacts (costs, benefits and impacts on the nation's economy of different policy choices), environmental impacts (most frequently, major air pollutant emissions).

A host of models are available to evaluate the economic impacts of energy policies, including policies designed to enhance security. These include (generically):

- **Bottom-up** models, in which the future need for fuels, and hence the costs of providing fuels, is derived based on demand for energy services and on the technologies that provide the energy services. Bottom-up models present a deterministic picture of the future, although sensitivity and scenario analyses can be used with bottom-up models to obtain some sense for which policies might yield a lowest-cost solution. Bottom-up models, however, often lack realistic mechanisms to model the feedback between energy prices, economic performance, and consumption.
- **Optimization** tools, find the economically optimal (for example, "least-cost") mix of technologies for a set of inputs under given constraints. This approach can be rich in technical detail and forward-looking in its technological assumptions. Optimization models are designed to maximize an "Objective Function" to find an optimal plan or policy approach, subject to financial, resource, or other constraints. These models are usually based on a "Reference Energy System" or a similar system of linear equations. The complexity of the mathematical algorithms involved in an optimization model, however, often requires that key aspects of the energy system be simplified. Many policy and behavioral variables and constraints are difficult to parameterize and incorporate in these analyses. Optimization models also can be highly sensitive to relative price forecasts and the expected costs of technologies, which are, by definition, uncertain. As a consequence, optimization models are more typically used to model well-described parts of an energy system (such as a refinery or electricity grid). Optimization models can be time-consuming to run, and the model result are difficult to interpret.
- **Systems Dynamics Models** allow the modeling of system changes over time. These models use engineering control theory to simulate stocks and flows of energy and materials through a system, and are thus good for studying the interrelationships of variables between components of a system (such as changes in use of different kinds of fuels as a function of fuel taxes). Systems dynamics models are rarely used for whole energy systems, and are more often applied, for example, for a single manufacturing facility. Systems dynamics models have extensive and complex data requirements, including the initial conditions of the system modeled, and the precise relationships between components. As with optimization models, Systems dynamics models can be time-consuming to run, and their results can be difficult to interpret in a clear and meaningful way.

The environmental impacts of energy policy choices include those that are reasonably quantifiable, and those that are not so straightforward to estimate. Major types (sulfur and nitrogen oxides, greenhouse gases, particulate matter, and sometimes hydrocarbons) of air pollutant emissions are often fairly easy to quantify based on a knowledge of the types of fuels being consumed in any given year, although a knowledge of the types of combustion technologies used is helpful in making estimates of (particularly) non-CO_2 emissions.

One technique of broadening the number of attributes evaluated using a least-cost-type optimization model is to ascribed monetized costs to various environmental emissions and impacts (for example, dollars per tonne of sulfur or of carbon dioxide emitted), then include the total costs of emissions (tonnes of emissions times dollars per tonne, summed over the types of emissions included) within the model's objective function creating a sort of "social cost" function. This approach, while it leads to a single metric with which to judge alternative plans and policies (and is thus conceptually appealing), is (as noted in Dr. Razavi's paper) subject to the many inaccuracies involved in computing (or imputing) values or costs of emissions, and also tends to limit the possibilities of "studying and demonstrating the trade-offs of various impacts of policy decisions".

For the less quantifiable environmental impacts (and, often, to incorporate the actual or potential damages caused by quantifiable emissions), it is necessary to resort to careful consideration by knowledgeable individuals, although impact models (including, for example, transport and deposition models for acid precipitation) can be helpful as well.

5.3.2. Diversity indices as tools for evaluating aspects of energy security

In his paper (presented in Attachment Set A), Thomas Neff borrows from the economics and financial analysis communities and other disciplines to create a set of tools, based on diversity indices, that can help to provide a metric for the energy security implications of different energy supply strategies[rr].

Dr. Neff starts with a simple diversification index, the Herfindahl index, written in mathematical terms as:

$$H = \sum_i x_i^2$$

where x_i is the fraction of total supply from source "i". This index can, for example, the types of fuels used in an economy (where x_i would then be the fraction of primary energy or final demand by fuel type). Alternatively, within a single type of fuel (such as oil), the index could be applied to the pattern of imports of a particular country by supplier nation. The index has a maximum value of 1 (when there is only one supplier or fuel type), and goes down with increasing diversity of number of suppliers or fuel types, so that a lower value of the index indicates more diverse, and (perhaps) more robust, supply conditions.

Consideration of risk in specific fuel import patterns can be worked into the above index, Dr. Neff argues, through consideration of the variance in the behavior of each supplier, and by application of correlation coefficients that describe how variance in the behavior of pairs of suppliers (for example, oil exporters Saudi Arabia and Indonesia) are or might be related. The correlation might be positive, for countries that tend to raise and lower their exports together, or negative, as when supplier "A" would tend to increase production to compensate for decreased production by supplier "B".

Dr. Neff also addresses the topic of market, or systematic risk, that is, the risk associated with the whole market—be it a market for stocks, oil, or uranium—changing at once. Applying parameters

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[rr] Readers are encouraged to consult Dr. Neff's paper for a much more thorough explanation of the derivation and application of the diversity index method than can be provided here.

that describe the degree to which individual suppliers are likely to change their output when the market as a whole shifts (the contribution of the variance of an individual supplier to overall market variance) allows the calculation of the variance of a given energy supply pattern. Hence, calculation of such as "portfolio variance) provides a measure of the relative risk inherent in any given fuel supplier pattern versus any other.

5.3.3. Multiple-attribute analysis and trade-off analysis

Deciding upon a single set of energy policies (or a few top options) from a wide range of choices is a complex process, and should be approached systematically if the result of the choice is to be credible. There are many different methods, with many gradations, for deciding which set of policies or energy path is/are the most desirable. These range from simply listing each attribute of each policy set or path in a large matrix (for example, on a chalkboard in a conference room) and methodically eliminating candidate paths (noting why each is eliminated), to more quantitative approaches involving "Multiple Attribute Analysis".

In one type of application of multiple attribute analysis, each criterion (attribute) used to evaluate energy policies or paths is assigned a numerical value. For objective criteria, the values of the attributes are used directly (present value costs are an example), while subjective criteria can be assigned a value based (for example) on a scale of 1 ("worst") to 10 ("best"). Once each attribute has a value, a weight is assigned to each attribute. These weights should reflect a consensus as to which attributes are the most important in planning[ss]. Multiplying the values of the attribute by the weights assigned, then summing over the attributes, yield "scores" for each individual policy set or path that can be compared. Although this process may seem like an attractive way to organize and make more objective a complicated decision/evaluation process, great care must be taken to apply the analysis so that 1) all subjective decisions—for example, the decisions that go into defining the system of weights used—are carefully and fully documented, and 2) the system used avoids magnifying small differences (or minimizing large differences) between policy or path alternatives.

Whatever tool or technique is used to decide between policy sets or paths, it is ultimately the people involved in policy-making who will decide which policies are to be implemented, or which energy path is worth pursing. As a consequence, one of the most important rules of the application of multiple-attribute analysis to an evaluation of policies is to present the analytical process in an open, clear, and complete manner, so that others who wish to review the decisions and assumptions made along the way can do so.

The analytical framework presented by Dr. Razavi in his paper Economic, Security, and Environmental Aspects of Energy Supply A Conceptual Framework for Strategic Analysis of Fossil Fuels, is a variant of multiple-attribute analysis (or "Trade-Off Analysis") that focuses on several energy security-related variables. Dr. Razavi identifies the steps in applying his method as:

1. Identify the objective attributes (for example, cost of energy, tonnes of SO_x or tonnes of CO_2);

[ss] Often, in instances where the groups participating in policy evaluation have different viewpoints, different sets of weights will be used to reflect different perspectives as to which attributes are the most important.

2. Identify policy decisions (for example, mix of fuels, petroleum reserve levels, or emphasis in technology development/deployment);
3. Identify exogenous variables (such as energy demand, international oil prices, or economic growth);
4. Determine plausible values for each policy and exogenous variable;
5. Form a database of all possible combinations of policy and exogenous variables, thus defining a range of different "plans" (or energy paths);
6. Measure the impact of each plan on all objective attributes (the value of each attribute for each plan);
7. Considering the attribute impacts of each plan, eliminate plans that are clearly inferior to others; and
8. Prepare a short list of plans for presentation to policy-makers.

In order to reduce the dimensions of the analysis to a manageable few, Dr. Razavi proposes concentration on two policy decisions—that appropriate mix of fuels and the desirable level of petroleum inventories—and four exogenous factors—growth in energy demand, the international price of crude oil, the potential for oil supply disruption, and the availability of natural gas.

The analytical system is designed so that plans that are clearly inferior or unacceptable, including those, for example, with exceptionally high costs or exceptionally high environmental emissions, can be relatively easily identified and eliminated, leaving those plans with reasonable combinations of attribute values/impacts for further consideration.

As noted by Dr. Razavi, the "Trade-off analysis" method is not well suited to short- or medium-range planning, as the number of policy variables and attributes required may be too large. The strength of the method is rather for planning longer-term energy strategies, where the decision of interest is between fairly different, and fairly abstract, policy directions.

5.4. Evaluating Energy Security In the Broad Sense—A Draft Framework

Borrowing heavily from Dr. Razavi's analytical structure, and incorporating some of Dr. Neff's techniques, we present the following draft framework for the analysis of the comprehensive energy security impacts of different energy policy sets. In this framework, we use the tools of multiple attribute analysis to provide an overall structure, and attempt to evaluate both objective attributes—those for which numerical values can be estimated—and subjective attributes for which quantification is problematic. The framework shown is designed to encompass the full range of energy security issues as we have identified them in this report, but is not designed to be a rigid structure. We hope that, in its final form, the framework will serve as a guide for and be adaptable to many energy security analyses at many different levels of detail, and for different country and policy applications.

5.4.1. Overall steps in approach

The basic steps in the draft framework we propose are:

- Define objective and subjective measures of energy security
- Develop candidate energy paths (and/or longer-term scenarios)

- Test relative performance of paths/scenarios by evaluating measures of energy security
- Incorporation of the elements of risk from unforeseen events (including accidents, natural disasters, war….)
- Comparison of path and/or scenario results—including quantitative and qualitative comparisons
- Elimination of energy paths that lead to clearly sub-optimal or unacceptable results

5.4.2. Objective and subjective measures of energy security

Table 5-1 presents our list of the various dimensions of energy security, and the attributes of those dimensions that might be used to evaluate different energy policy choices. Although additional attributes to measure energy security can doubtless be found, we have tried to err on the side of providing a broadly inclusive list. It is probable that no single analysis of energy security would use all of the attributes below, and there is some redundancy between attributes that probably could be eliminated through judicious selection.

Table 5-1: Dimensions and Attributes of Energy Security

Dimension of Energy Security	**Attributes**	**Interpretation**
Energy Supply	Total Primary Energy	Higher = indicator of other impacts
	Fraction of Primary Energy as Imports	Lower = preferred
	Diversification Index (by fuel type, primary energy)	Lower index value preferred
	Diversification Index (by supplier, key fuel types)	Lower index value preferred
	Stocks as a fraction of imports (key fuels)	Higher = greater resilience to supply interruption
Economic	Total Energy System Internal Costs	Lower = preferred
	Total Fuel Costs	Lower = preferred
	Import Fuel Costs	Lower = preferred
	Economic Impact of Fuel Price Increase (as fraction of GNP)	Lower = preferred
Technological	Diversification Indices for key industries (such as power generation) by technology type	Lower = preferred
	Diversity of R&D Spending	Qualitative~~Hi~~gher preferred
	Reliance on Proven Technologies	Qualitative~~Hi~~gher preferred
	Technological Adaptability	Qualitative~~Hi~~gher preferred

Table 5-1 (cont.): Dimensions and Attributes of Energy Security

Dimension of Energy Security	**Attributes**	**Interpretation**
Environmental	GHG emissions (tonnes CO_2, CH_4	Lower = preferred
	Acid gas emissions (tonnes SOx, NOx)	Lower = preferred
	Local Air Pollutants (tonnes particulates, hydrocarbons, others?)	Lower = preferred
	Other air and water pollutants (including marine oil pollution)	Lower = preferred
	Solid Wastes (tonnes bottom ash, fly ash, scrubber sludge)	Lower = preferred (or at best neutral, with safe re-use)
	Nuclear waste (tonnes or Curies, by type)	Lower = preferred, but qualitative component for waste isolation scheme
	Ecosystem and Aesthetic Impacts	Largely Qualitative~~Lo~~wer preferred
	Exposure to Environmental Risk	Qualitative~~Lo~~wer preferred
Social and Cultural	Exposure to Risk of Social or Cultural Conflict over energy systems	Qualitative~~Lo~~wer preferred
Military/Security	Exposure to Military/Security Risks	Qualitative~~Lo~~wer preferred
	Relative level of spending on energy-related security arrangements	Lower = preferred

5.4.3. Candidate Energy Paths

An energy path describes the evolution—or potential evolution—of a country's energy sector assuming that a specific set of energy policies are (or are not) put in place. The level of detail with which an energy path is described will be a function of the degree of realism required to make the path analysis plausible to an audience of policy-makers, as well as the analytical resources (person-time) and data available to do the analysis. "Bottom-up" quantitative description of energy paths—like the ones we present in the next chapter of this report—offer the possibility to specify fuels and technologies used, as well as energy system costs, and key environmental emissions, in some detail, but can require a considerable amount of work, particularly if they are . Simpler econometric models (or models that combine econometric and end-use elements) can also be used, providing that model outputs can include measures of energy security like those presented above. A major criterion to keep in mind, when developing energy paths, is that the paths chosen should be both reasonably plausible, yet different enough from each other to yield, when their attributes are compared, significant insight into the ramifications of the energy policy choices that the paths describe.

At times it may be helpful to look farther into the future than charting of an "energy path" will permit. In such instances, the use of scenario analysis may be helpful. This technique, described in Chapter 7 and in the paper by Paul Mlotok in Attachment Set A**,** allows a group of knowledgeable people, working together, to look into the future to postulate the results of near- and mid-term policy directions, or to suggest policy directions that could increase the probability of various energy security outcomes (both desirable and undesirable).

5.4.4. Evaluate measures of energy security

Once the energy paths are specified, the next step is to evaluate the objective and subjective measures listed in Table 5-1, or as large a subset of those measures is practicable and desirable. In many cases, the use of economic models or other computational tools will be in order to perform measures evaluations.

5.4.5. Incorporation of the elements of risk

In his paper, Dr. Razavi lists six methods used for the analysis of risk and uncertainty in energy planning. These methods are:

1. **Scenario Analysis**—used to "arrive at policy decisions that remain valid under a large set of plausible scenarios".
2. **Sensitivity Analysis**—where variations in one or more plans (or paths) are studied when key uncertain parameters are varied;
3. **Probabilistic Analysis**—in which "probabilities are assigned to different values of uncertain variables, and outcomes are obtained through probabilistic simulations";
4. **Stochastic Optimization**—in which a probability distribution for each uncertain variable is assigned during an optimization exercise;
5. **Incorporating Uncertainty in the discount Rate**; and
6. **Search for a Robust Solution**—which Dr. Razavi describes as using "the technique of trade-off analysis to eliminate uncertainties which do not matter and to concentrate on the ranges of uncertainty which are most relevant to corresponding objective attributes".

Although any or all of these six techniques could be applied within the energy security analysis framework that we suggest, probably the most broadly applicable and transparent of the techniques above are scenario analysis, sensitivity analysis, and "search for a robust solution". In our analysis of the energy security implications of two different medium-term energy paths for Japan, we use a combination of scenario analysis and sensitivity analysis to test the response of the different energy paths to extreme changes in key variables.

5.4.6. Comparison of path results: quantitative and qualitative comparisons

Once attribute values (and qualitative assessments) have been compiled for each of the energy paths, the next step is to compare the values. Here, as indicated above, it is possible to ascribe weights to each attribute and thus devise one or more overall indices of "energy security", but the most straightforward approach is probably to simply line up the attributes values for each path side by side, and review the differences between paths, focusing on differences that are truly significant. For example, if the difference in net present value (NPV) cost of plan "A" is one billion dollars greater than that of plan "B", the difference must be examined relative to the overall cost of the energy system, or to the cost of the economy as a whole. To an energy system that costs, say, one trillion (10^{12}) dollars in capital, operating and maintenance, and fuel costs over 20 years, a difference between plans of one billion (10^{9}) dollars is not only trivial, it is dwarfed by the uncertainties in even the most certain elements of the analysis. The key, then, is to search for differences between the attributes of the plans—taking care to include both qualitative and quantitative attributes—that are truly meaningful.

5.4.7. Elimination of paths that are clearly unacceptable or sub-optimal

The side-by-side comparison of candidate paths should, if the original set of paths considered was sufficiently broad, allow the elimination of paths that are clearly worse, in several (or key) attribute dimensions, than other candidates. The process of elimination of paths, should, however, be approached in a systematic, transparent, and well-documented way.

5.5. Placing Energy Paths/Policies in Broader Context

When reviewing the energy security attributes of a given energy path or set of prospective energy policies, it is important to keep in mind that national energy policy and national energy security have impacts beyond the more immediate future and beyond national borders. As a consequence, it is important to consider the ramifications of different energy paths within the context of longer-term energy scenarios and/or goals (for example, 1998 to 2050 or 2100), as well as in the context of changes at the regional and global levels. A particular country may come up with a set of energy policies that appear to serve the country well until, say, 2020, but a look at how the proposed policies will affect or be affected by potential changes at the regional or global level may make the policy set look less attractive. A few quantitative analytical tools are available to assist in this process of looking beyond the temporal and spatial borders of a national energy security analysis[tt]. Nonetheless, qualitative tools like scenario building and good old-fashioned thinking and discourse are the principal requirements for placing national energy security analysis in context.

5.6. Other Questions and Topics for Further Research

There are a number of elements of the draft analytical framework presented above that could be strengthened with further research. Some of the questions about the analysis of energy security that we would like to see addressed (in no particular order of importance) are:

- What is the most expedient way to reflect the impact of changes in energy prices, taxes, or shortages in fuel supplies on economic productivity?
- What expedient methods exist to establish (or estimate) the variance and covariance of suppliers and fuel types for calculation of diversification indices?

[tt] The "Polestar" software tool, developed by the Stockholm Environment Institute—Boston Center with support collaboration from many nations, is an example of a tool for long-term, global scenario building. (See, for example, P. Raskin and R. Margolis (1995) Global Energy in the 21st Century: Patterns, Projections, and Problems (Polestar Series Report No. 3), Stockholm Environment Institute, Stockholm, Sweden).

- What methods and data are available for the calculation of military-security impacts of different energy policy choices?
- How should a group of researchers decide on when the range of energy paths or energy policy sets considered are adequate to ensure a robust analysis?
- What is the most straightforward way to document subjective choices as to the weighting of energy security attributes?
- What changes in the analytical structure (Creation of a decision-support tool? Streamlining of the structure to remove attributes less important to or affected by energy policies?) will help to usefully bring the benefits of energy security analysis—in the broad sense—to the arenas where energy policy is formulated?
- Although it is worthwhile to focus analysis on particular parts of the energy security puzzle—nuclear power and the use/re-use of plutonium is a key example of interest to many members of the PARES Working Group—how does one make sure that such analysis takes adequate account of the broader energy security context?

6. Energy Demand/Supply Model and Paths for Japan

6.1. Introduction

In order to evaluate the impacts of different approaches to providing “energy security”—with all of its broad and complex meanings and ramifications (as described above)—it is helpful to have a detailed and quantitative (when possible), yet transparent, model of the energy system under study. Also helpful is a clear and transparent methodology for reviewing the potential of different energy paths or scenarios to lead to a more (or less) “secure” energy future. As a part of the Japan case study of the concept of energy security in the Pacific Asian region, we have assembled two medium-range (1990 to 2020) energy “paths” that describe the evolution of energy demand and supply in Japan. Descriptions of the two energy paths—which are designed to produce similar levels of energy services[uu]—are provided below. Note that neither of the two paths are specifically designed to represent the most “likely” or “optimal” energy path for Japan. The goal in preparing and evaluating these energy paths is primarily to use the paths as quantitative “test-beds” for our development of methods for the evaluation of measures and policies designed to increase energy security.

The general outlines of the two paths are as follows:

1. ***Business-As-Usual (or “Base Case”) Path***: Largely follows and extrapolates recent trends in energy demand, energy supply investment, and environmental emissions control, with continued emphasis on fossil fuel use and only modest increases in energy efficiency and in the use of renewable energy. In effect, the business-as-usual path includes nuclear power as an approximately constant fraction of total generation, increasing use of oil for transport, and continuing substitution of natural gas for other fuels in end-use sectors.

2. ***“Alternative” Path***: Includes increased emphasis on substitution of natural gas for coal and oil in both end-use demand sectors and electric power generation, plus aggressive application of end-use efficiency improvement and renewable fuels in all sectors. This path keeps the fraction of power supplied by nuclear energy roughly the same as at present, but the generation and capacity required is reduced due to efficiency improvements.

6.2. Software Tools Used for Path Elaboration and Evaluation

Elaboration and a portion of the evaluation of these paths was carried out using the LEAP (**L**ong-range **E**nergy-environment **A**lternatives **P**lanning) software framework[vv]. LEAP provides a convenient, transparent structure for database development, generation of variant energy paths, and

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[uu] Energy services are the services that fuel use provides. Examples are the production of a tonne of steel, the cooking of a meal, or transport of a passenger one kilometer. The same energy service can usually be provided using different types and amounts of fuel, depending on the technology used. As a consequence there are often opportunities to modify the energy security impacts of providing energy services (for example, by reducing the use of key fuels, or reducing the environmental impacts of energy services) without reducing the actual amount of energy services provided.

[vv] LEAP and the LEAP “family” of software tools have been developed by the Stockholm Environment Institute—Boston Center, Boston, MA, USA. A brief description of LEAP and the other software tools in the LEAP family is provided in Attachment Set D to this report

evaluation of internal and (some) environmental costs of energy-sector changes. LEAP starts as a "blank slate" into which the user enters an ordered description of energy demand and supply in the area (which can be a village, state, country, region, or globe) under study. LEAP provides functions that make it straightforward to calculate, change, recalculate, and report results at many different levels of detail. As both a benefit and a burden of its transparent, end-use (demand)-driven structure, economic and pricing assumptions in LEAP (and their impact on energy demand) must largely be supplied by the user, although simple econometric equations can be used to "drive" energy demand in specific sectors, subsectors, or end-uses. LEAP is not an optimizing model, but candidate variants of energy paths can be quickly assembled and tried in order to meet specific criteria (such as cost, fuel diversity, or environmental constraints). Other software could be used to supplement the analysis of energy paths—and considerable post-processing of LEAP results for the two energy paths with custom spreadsheet tools is required to address many energy security questions.

We should stress that our choice of the LEAP software system as a tool for the current analysis was in part influenced by the familiarity of some members of the team with the attributes of LEAP, and in part because LEAP's attributes fit our criteria for a modeling aid, namely that our framework be an open, transparent structure that is transferable and is usable in other contexts and for other areas—for example, for other countries in the Northeast Asia region. There are other modeling tools that can perform some of the same functions as LEAP, and in fact, there is nothing that LEAP does that could not be done in a (largish) spreadsheet model. By the same token, although LEAP can help to generate useful reports for some parts of energy security analyses, there are many elements of energy security, as we have broadly defined the concept, that can really only be addressed and evaluated through good old-fashioned thinking—careful consideration of energy security criteria, options, and ramifications. As a consequence, the framework proposed in this report is not intended to stress one software tool or analytical approach over another, but rather to indicate the range of criteria and tools that can and should be applied when studying the energy security impacts of different policies and measures.

6.3. Energy Sector Model for Japan: Base Year Values, and Common Assumptions

Our models—both the BAU and alternative paths—begin with a description of the status of Japanese energy demand and supply in 1990 and 1995. The main source the we used for recent Japanese energy data has been a set of very detailed (41 fuel categories by 45 rows) Japanese-language energy balances complied by the Japanese Institute for Energy Economics (IEEJ) and the Energy Conservation Center, and published by the MITI (Ministry of International Trade and Industry) Research Institute. These data were augmented by data from the USDOE EIA (the US Department of Energy's Energy Information Administration), the IEA (International Energy Agency), United Nations documents, a statistical compendium of Japanese energy and economic statistics, Japanese government statistics World-Wide Web (WWW) sites, and other sources. We were also fortunate (and grateful) to obtain a set of very detailed spreadsheets that provided historical energy and related data by end-use for each of the major sectors of the Japanese economy. These spreadsheets, developed by the International Energy Studies Group of Lawrence Berkeley National Laboratory, were used to provide additional end-use detail in many sectors[ww].

[ww] These Microsoft Excel™-based spreadsheets, supplied by Lee Schipper and Michael Ting of Lawrence Berkeley National Laboratory, Berkeley, California, USA, include data complied from a collection of Japanese statistical publications and unpublished information from energy researchers in Japan. Citations to the individual spreadsheets from which data were taken are provided in the sector-specific sections of Attachment D.

In assembling the demand side of our model of Japan's energy sector, our goal was to provide sufficient sectoral, subsectoral, and end-use detail to be able to model the introduction of specific measures and technologies designed to increase the efficiency with which energy services are supplied, or designed to shift from the use of one fuel to another. In some cases, we did not have sufficient base year (1990 to 1995) data to provide the degree of disaggregation we might have wanted, but in most cases, through a combination of existing data, estimates made by others, and our own estimates, we were able to devise an end-use structure that seemed reasonable and consistent with recent historical data. The data and assumptions that we used in preparing our quantitative descriptions of energy supply and demand in Japan are presented in the data preparation spreadsheet "NEA_JPN5.XLS", a printout of which is presented in Attachment Set D.

In some sectors and subsectors, GDP (Gross Domestic Product) was used as a driving variable. Estimates of future GDP by sector as presented in the table below were assumed. The approach used in preparing these estimates was to start with GDP growth estimates to 2015 as taken from the "Standard Case" estimates by the Institute for Energy Economics, Japan[11, xx]. GDP growth rates in key sectors and subsectors of the Japanese economy were then estimated based on a combination of recent trends in the Japanese economy and estimates of sectoral/subsector GDPs from a World Wide Fund for Nature (WWF-Japan) study of the potential to reduce CO_2 emissions in Japan[12]. The goal was to prepare a set of sectoral/subsectoral GDP growth estimates roughly consistent with the estimate for overall GDP, as shown in Table 6-1.

Table 6-1

Estimates of Future GDP by Sector

(Trillion 1985 Yen)

	Historical/Estimated Values			Annual Growth Rates		
	1990	1992	1993	1993-2000	2000-2010	2010-2020
Total GDP	399.09	420.83	425.74	2.5%	2.2%	1.9%
Manufacturing GDP	116.04	117.55	114.15	2.4%	2.4%	1.9%
Transport/Communic GDP	25.48	26.35	26.32	2.8%	2.2%	2.0%
Sum of Commercial Sect	218.46	230.33	235.09	2.8%	2.2%	2.0%
Mining and Quarrying	1.2023	1.208	1.2132	-1.0%	-1.0%	0.0%
Construction	39.60	42.60	43.74	1.1%	1.6%	1.2%
Sum of Listed Subsectors	400.78	418.05	420.51	2.51%	2.19%	1.90%

Other key assumptions used for both energy paths, organized by sector, are presented below:

- In the **Household Sector**, we assumed figures for population growth taken from the Japan Department of the Census Projections (figures in millions): 1995 = 125.57; 2000 = 127.39, 2010 = 130.40, 2020 = 128.35. These figures are somewhat higher than levels assumed in the WWF-Japan report. The number of persons occupied dwelling declined from 3.17 in 1990 to 2.997 in 1995, an average decline of 1.13 percent/yr. We assumed that this indicator of average household size would continue to decline, but not as steeply as in the recent past: 1.0 percent/yr through 2000, 0.5 percent/yr to 2010, and 0.2 percent/yr thereafter. The combination of population growth and a reduction in the number of persons per occupied dwelling results in an increase in the number of households at a rate of about 1.3 percent per year from 1995 through 2000 and about 0.74

[xx] These GDP estimates appear to be an update of the projections presented in Fujime, K. (1996), "Energy Situations in the 21st Century", Energy In Japan No. 138, March, 1996. Overall GDP growth in the newer IEEJ projections are somewhat lower than those presented by Fujime.

percent/yr from 2000 to 2010, growing very little thereafter. Our model of the household sector is divided into four end-uses: space heating, water heating, cooking, and “other electrical appliances”, each of which is in turn divided into different devices (for example, stoves that use different fuels) that are used within each end-use.

- In the **Commercial/Public/Services Sector**, we assume that energy use generally is driven by the amount of floor space used businesses and institutions (commercial floor space). Between 1990 and 1995, the amount of floor space increased significantly faster than the level of GDP growth in the commercial sector. We assume that the ratio between commercial GDP and floor space will remain constant over the next 25 years. Note that this assumption is somewhat different than that used in the WWF-Japan study, where “Office Space” is assumed to grow more slowly than commercial GDP. As a result of this difference in assumptions, the amount of commercial space we assume will be in use in Japan by 2010 (2,130 million square meters) is more than 10 percent higher than the space assumed in use in the WWF-Japan study. Although our model of the commercial sector does not differentiate by subsectors (for example, office buildings, health facilities, retail), we divide energy end-use in the commercial sector into four categories: non-electric fuels, electric heating and water heating, electric cooling, and lighting plus other uses of electricity.

- In the **Industrial Sector**, our assumptions for subsectoral activity include:

  ⇒ In the **water treatment** subsector, the volume of water to be treated scales with population.

  ⇒ **Mining and quarrying** subsectoral GDP is assumed to fall at an average rate of 1.0 percent/yr from 1993-2010[yy], with no change (in real terms) thereafter.

  ⇒ **Processed food** output is assumed to increase at 1.3 percent/yr (comparable to recent trends) from, 1993 to 2000 and 0.75 percent/yr from 2000 to 2010, with no change, on average, thereafter (as population starts to decline)

  ⇒ Output of **textiles and fiber**, which contracted sharply in the early 1990s, is assumed to continue to decline at 5 percent/yr through 2000, then at 2.5 percent/yr from 2000 to 2010, remaining stable thereafter.

  ⇒ Output of **paper and paperboard**, and of **chemicals**, is assumed to increase at 1.0 percent/yr (comparable to recent trends) from, 1993 to 2000, and at 0.5 percent/yr from 2000 to 2010, with no change, on average, thereafter.

  ⇒ **Ceramics** output is set to increase by 1.0 percent/yr (somewhat lower than the growth rate in cement output from 1990 to 1995, but output in 1995 seems to have been unusually high) through 2000, then at 0.75 percent/yr from 2000 to 2010, and 0.5 percent/yr from 2010 to 2020.

  ⇒ Output of **iron and steel** decreased during the early 1990s. We assume that the decrease continues at 1.5 percent/yr through 2000, changing to a decline of 1 percent/yr through 2010, and at 0.5 percent/yr thereafter.

  ⇒ Manufacturing GDP (a benchmark for the **Non-ferrous Metals, Metal Finishing**, and **Other Manufacturing** subsectors) is assumed to grow at 2.4 percent/yr from 1993 to 2010, with growth of 1.9 percent/yr thereafter. These growth rates reflect an assumption of

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[yy] Mining and quarrying GDP in 1995 alone was nearly 25 percent less than in 1993.

manufacturing sector performance that is substantially better than has been experienced in the Japanese economy in recent years, but is roughly consistent with assumptions cited in the WWF-Japan report.

- In the **Transport** sector, our model for energy consumption is split into three subsectors: passenger transport via taxis and mass transit (buses, trains, planes, and ferries), private vehicles (cars, trucks, and cycles), and freight transport (truck, rail, air, and water freight). Table 6-2 presents our assumptions as to overall activities in these subsectors. Overall, our assumption is that passenger transport, and passenger transport per capita, will continue to increase, but at rates progressively lower than in the recent past (passenger-kilometers traveled per capita increased at an average rate of 2.6 percent per year between 1990 and 1995). Our assumptions for overall levels of passenger transport are slightly higher, in 2000 and 2010, than those assumed in the WWF-Japan study. We assume that the stock of private vehicles will likewise continue to grow, but that growth in the number of private vehicles will slow in 2000 to 2020 relative to the growth (1.8 percent/yr) experienced from 1990 to 1995. The volume of freight transported in Japan drifted up and down during the first half of the 1990s; average growth was about 0.4 percent per year. We assume that the tonne-kilometers of freight transport grows at a somewhat faster rate than recently experienced, slowing slightly as economic growth slows down after 2010. Our assumed growth in freight transport between 2000 and 2010 is lower than that assumed in the WWF-Japan study.

Table 6-2:

Summary of Key Input Assumptions: Transport Sector

			Growth Rate (%/yr) From			Implied Values for		
TAXIS AND MASS TRANSIT	1990	1995	95 - 2000	2000-2010	2010-2020	2000	2010	2020
Total Pass-km (billion)	1,223	1,415	1.79%	1.74%	0.84%	1,546	1,836	1,997
Passenger-km/capita	9,897	11,265	1.50%	1.50%	1.00%	12,135	14,084	15,557
PRIVATE ROAD VEHICLES*								
Total Vehicles (Thousands)	72,430	79,339	1.50%	1.00%	0.50%	85,470	94,412	99,240
Impl. % pass-km in autos/cycles	53.3%	58.9%	1.22%	0.46%	-0.06%	62.5%	65.5%	65.1%
Impl. Bpass-km in autos/cycles	652	833	3.03%	2.20%	0.78%	967	1,202	1,299
FREIGHT TRANSPORT**								
Total tonne-km (billion)	547	559	0.75%	0.65%	0.50%	580	619	651

*"Private Buses" included in Taxis and Mass Transit

**Freight transport by "Private Trucks" is included in Private Road Vehicles

We assume that the use of "marine bunkers" (fuel placed into storage for use in international shipping) scales with the amount of international freight loaded and unloaded, which in turn increases at the same rate as domestic freight transport. We assume that the use of bunker fuels in international aviation scales with the number of international air passenger kilometers, which is assumed to grow at 3.0 percent per year from 1995 to 2000, at 2.0 percent/yr from 2000 to 2010, and at 1.5 percent per year from 2010 to 2020. Recent (1990 to 1995) has been higher, averaging 6.7 percent per year, thus we postulate somewhat of a "leveling-off" in demand for international travel.

- Total sectoral output in the **Agricultural/Fisheries/Forestry Sector** is assumed to have no real growth from 1993 on. Agricultural production in general has been declining, overall, since 1990[13], and forestry and fisheries income have shown similar trends[14].

The subsections that follow present our assumptions, both quantitative and qualitative, for each of our two main "paths" that take the Japanese energy sector through the year 2020. Following these descriptions is a presentations of variants of the two paths—essentially, changes in the paths that test the robustness of each path to a major external disruption.

6.4. Description of Assumptions for Business-as-Usual Path through 2020

Our general assumptions for the “Business-as-usual” (BAU) path are presented below, including assumptions as to changes in energy demand and supply[zz], as well as assumptions as to how various types of risk that bear on energy security would (in our view) be dealt with in Japan under a BAU world.

6.4.1. Energy Demand in the BAU path

Assumptions as to the elements of future energy demand under the BAU path, including trends in both technology use and energy intensities, are described below, by demand sector.

HOUSEHOLD SECTOR

In the **household space heating** end-use, we assume that the relative share of non-electric heat supplied by LPG (liquefied propane gas) and kerosene decline slowly, and that the use of city gas (municipal gas) increases at 1 percent per year from 1995 to 2010, and at 0.5 percent per year thereafter. The use of solid fuels for home heating is assumed to continue to decline, reaching zero (for coal) or negligible (wood and charcoal) levels by 2010. The fraction of households heated with district heating systems is assumed to remain at 1995 levels. The overall use of non-electric heating fuels per occupied dwelling is likewise assumed to be constant from 1995 onward[aaa]. Among electric heating appliances, we assume that the number of “hot air heaters” per dwelling declines at 0.5 percent/yr after 2000, the number of heat-pump and “electric carpet”-type heaters per dwelling increases (although at diminishing rates) through 2020, and the number of foot warmers and electric blankets per household remain constant (on average) from 1995 through 2020. Extrapolating (roughly) from recent trends, we assume that the unit electricity usage (GJ of electricity per unit-year) of hot air heaters and electric carpets increase over time, the unit electricity usage in heat pump-type heaters decreases, and that the consumption of electricity per unit in other heating appliances remain at 1995 levels.

In **household water heating**, we assume that that technologies follow similar patterns as for household space heating. The fraction of water heating provided by LPG and kerosene-fueled units is assumed to decline slowly, while the fraction of homes with water heaters fueled with natural gas is assumed to continue to increase, coal use is assumed to continue to decrease (stabilizing at a low level), and the fraction of water heat provided by wood/charcoal, electric, solar, and district heat remain at 1995 levels. The intensity of energy use (GJ per dwelling) for water heating (with the exception of solid

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[zz] Please see Attachment D for additional details of our assumptions as to energy demand and supply patterns under both of the energy paths described in this Chapter.

[aaa] Use of non-electric heating fuels per household varied substantially during the period from 1990 to 1994 even when considered on a climate-corrected (accounting for some of the changes in the weather from year to year) basis. Our assumption of no change in the intensity of non-electric fuels use can be thought of (roughly) as a stalemate between the trend toward increasing household floor area (and thus greater heated area) and improved efficiency of fuel use.

fuels and solar water heat) is assumed to decline over time, at a rate about half of the rate of decline in household size.

In the **household cooking** end-use, we assume that the fraction of LPG (currently the dominant non-electric cooking fuel in Japan) continues to decrease slowly, and the fraction of households using municipal gas continues to increase (at 1.0 percent per year through 2010, and 0.5 percent/yr thereafter). We assume that the fraction of households using electric rice cookers and microwave ovens continues to increase, but at a reduced rate as the ownership of these types of appliances approach saturation[bbb]. The annual per household use of each type of cooking fuel (or of electricity per electric cooking appliance) is assumed to remain unchanged from 1995 on.

For **other electric appliances used in the household sector**, we assume that the number of heat pump-type coolers per dwelling continue to expand, albeit at a reduced rate of expansion, as per recent trends (2.0 percent per year from 1995 to 2000, 1.0 percent per year from 2000 to 2010, and 0.5 percent per year thereafter). The ownership of other electric appliances per household (with the exception of second television sets and clothes dryers, which are assumed to continue to increase their market penetration through 2010) are assumed to remain at 1995 levels—typically at, near, or beyond the level of market saturation—through 2020. Our assumptions as to trends in unit usage for other electric appliances are presented in Table 6-3. With the exception of refrigerators, whose unit usage falls slightly over time (due to a combination of better technology and fewer persons per household), we assume that the use of electricity per unit in these appliances either remains at 1995 levels or, following recent trends, continues to increase. We assume that electricity use not explicitly accounted for in the list of appliances (or in other end uses) increases at a relatively brisk 3.0 percent per year through 2020, at 1.5 percent per year from 2000 to 2010, and at 0.5 percent/yr thereafter.

Table 6-3:

Unit Usage Estimates for Other Electric Appliances (GJ/unit-yr)

			Growth Rate (%/yr) From			Implied Values for		
	1990	1995	95 - 2000	2000-2010	2010-2020	2000	2010	2020
Heat Pump Cooler	0.540	0.439	0.00%	0.00%	0.00%	0.439	0.439	0.439
Room Cooler	1.194	1.282	0.00%	0.00%	0.00%	1.282	1.282	1.282
Fan	0.051	0.058	1%	0.50%	0.00%	0.061	0.064	0.064
Lighting	2.202	2.436	1%	0.50%	0.00%	2.560	2.691	2.691
Refrigerator w/ freezer	2.573	2.500	-0.50%	-0.30%	0.00%	2.438	2.366	2.366
Clothes washer	0.158	0.168	1%	0.50%	0.00%	0.176	0.185	0.185
Dryer	1.651	1.779	1%	0.50%	0.00%	1.870	1.965	1.965
TVC,1st	1.111	1.142	0.50%	0.30%	0.00%	1.171	1.206	1.206
TVC,2nd	0.299	0.348	1.50%	0.50%	0.00%	0.375	0.395	0.395
Vacuum	0.399	0.440	1%	0.50%	0.00%	0.463	0.486	0.486
other	4.994	6.602	3%	1.50%	0.50%	7.654	8.883	9.337

COMMERCIAL/PUBLIC/SERVICES SECTOR

In the commercial, public, and services sectors (which, for lack of disaggregated data, we have modeled as a single sector and refer to as “commercial”), we express energy intensities in terms of fuel use per unit of commercial floor space. The exception to this approach is for electricity use, which is divided into electricity for space and water heating, electric cooling, and electricity for lighting and other

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[bbb] To say that the ownership of an appliance is approaching “saturation”, in the case of these cooking devices, implies that most households own rice cookers and microwave ovens.

uses ("plug loads"). We assume that the use of coal, which has been rapidly decreasing in the commercial sector in Japan, will be discontinued by the year 2010, and the use of heavy oil "B" will be discontinued by 2020[ccc]. Both of these fuels are minor components of the commercial sector energy mix. We assume that the intensities (per square meter of floor space) of use of coke and diesel fuel (which are not heavily used in the sector) and of kerosene and heavy oil "A" (which are heavily used) will remain relatively constant from 1995 on. Continuing recent trends, we assume that the intensity of commercial-sector use of heavy oil "C" (one of the heaviest and "dirtiest" of the heavy oil grades) will be reduced by 5 percent/yr from 1995 to 2010, and at 3.0 percent/yr thereafter. The use of LPG, municipal gas, and district heating in the commercial sector is assumed to continue to increase. Among the uses of electricity in the commercial sector, electricity use per unit floor space for heating and cooling are assumed to increase 1.0 percent per year until 2000, and at half that rate until 2010, remaining stable thereafter. The use of electricity for lighting and other uses, which constituted about 87 percent of commercial-sector electricity use in 1995, is assumed to increase somewhat more quickly: 2.0 percent/yr from 1995 to 2000, 1.5 percent/yr from 2000 to 2010, and 1.0 percent/yr thereafter.

We assume that the average usage of electricity per household increases at 2 percent/yr through 1995 (it actually grew faster between 1990 and 1993), then remains constant, as improvements in efficiency (which have been slowing or stopping in Japan in recent years) and decreases in the number of persons per household (which should lower per-household use) are balanced by modestly increasing use of household energy services.

For other fuel use, it is assumed that household use of coal declines to zero by 2000, and household use of biomass (probably including charcoal) decreases 50 percent of its 1990 value by 2000, remaining constant thereafter. Kerosene use per household is assumed to increase at 1 percent/yr through 2000 (it grew much faster than that between 1990 and 1993), then remains constant until 2010, declining at 1 percent/yr thereafter. Municipal gas and district heat use are assumed to increases at 1 percent/yr after 1993, and LPG use stays constant throughout the period.

INDUSTRIAL SECTOR

In the nearly two decades between the first "Oil Crisis" of 1973 and the beginning of the 1990s, the efficiency with which energy was used in the industrial sector in Japan improved markedly. In recent years (1990 to 1995), however, energy use per unit output in the industrial sector in Japan has typically either shown little change or, in certain subsectors, increased[15]. Our BAU scenario assumes that in the absence of any marked increase in energy prices or policy imperatives, the overall energy intensities of industry will not change much except for a continuation of the trend toward the use of lighter, cleaner-burning fuels.

The intensities of electricity use in industrial subsectors in Japan are assumed, with the exceptions noted below, to remain constant at the 1995 level from 1995 through 2020. In the food products and textile and fiber subsectors, we assume that electricity use intensity increases at an average of about 0.8 percent/yr through 2010. In the ceramics and steel industries, electric intensity is assumed to continue to increase modestly until 2000, then remain constant.

[ccc] Recent trends shown by energy balances would seem to indicate an effort to reduce or eliminate the use of heavy oil "B" throughout the Japanese economy.

For other fuels used in industry:

- Water Treatment: 1995 intensities (which were higher for kerosene and diesel than 1990, lower for other fuels) are assumed to hold through 2020.
- Mining and Quarrying: It is assumed that 1995 intensities (which were higher for all fuels except blast furnace gas—which was not used in 1995—than in 1990) hold through 2020.
- Construction: 1995 intensities (which were somewhat higher for diesel, but lower for other fuels than in 1990) are assumed to not change through 2020.
- Food Products: To reflect the trend away from heavier fuels to gas and electricity, it is assumed that the intensity of heavy oil "A" use declines through 2020, "B" declines to zero by 2000, "C" declines rapidly between 1990 and 2000 (as per recent trends), and more slowly thereafter, and municipal gas use increases so that the overall intensity of non-electric fuels use declines slightly over time.
- Textiles and Fiber: For all fuels except heavy oil "B", energy intensities for this subsector increased modestly to significantly between 1990 and 1995. This may reflect reduced industry output with the same energy input, a shift in the product composition of industry output, or a change in accounting practices. The working assumption in the BAU case is that energy intensities stay the same from 1995-on as they were in 1995, except that municipal gas use continues to be phased in at an average of 5.7 percent/yr through 2020, and LPG is phased in at an average of 3 percent/yr through 2010, with these cleaner fuels approximately replacing heavy oil "C" and "A". Heavy oil "B" is phased out by 2000 in this subsector.
- Paper and Pulp, Chemicals, Ceramics, Steel, Non-Ferrous metals: It is assumed that 1995 intensities hold through 2020, except that municipal gas use continues to increase, replacing (where applicable) some heavy oil "C", heavy oil "A", coke, blast furnace gas, and coal use.
- Metal Finishing: 1995 intensities are assumed hold through 2020, again except for some shift away from heavy oil (and kerosene, in this case) to municipal gas.
- Other Manufacturing: 1995 intensities are assumed to hold from 1995 through 2020.

AGRICULTURAL/FISHERIES/FORESTRY SECTOR

The assumed changes for the aggregated agricultural, fisheries, and forestry sector in energy intensities by fuel are as follows:

- Heavy Oil B: Decreases to zero (as in 1993) by 1995.
- Heavy Oil C: Decrease to zero by 2000.
- All other fuels: from 1993 levels, increase at 0.5 percent/yr from 1995 until 2000 (roughly reflecting continued increases in mechanization, and shifts to more energy-intensive value-added products in agriculture), then no change through 2020.

TRANSPORT SECTOR

The overall trend in transport in Japan in recent years has been an increase in the use of road vehicles and airplanes for both passenger and freight transport, with a corresponding reduction in rail and water-borne transport. In the road sector, an additional trend has been toward increased ownership of private vehicles (cars).

Road freight in Japan is carried by two classes of vehicles, distinguished in statistical compilations as “private” and “commercial” road vehicles. Although “private” trucks outnumber “commercial” trucks by nearly 20 to one (as of 1995), most of the volume of freight transported, measured in tonne-kilometers, is carried out by “commercial” trucks. More than 70 percent of “private” trucks are fueled with gasoline, and most of those are (apparently) “mini” (or “Kei”) vehicles (engine displacement of less than 660 cubic centimeters) that are used for carrying small loads short distances in urban areas. “Commercial” trucks, on the other hand, are virtually all diesel fueled, and go much further each year (with heavier loads) than the average “private” truck. Lacking data that would allow us to separately estimate the volume of freight carried by private gasoline-fueled and private diesel-fueled trucks, we have modeled fuels consumption by private trucks on a per-vehicle basis; we have modeled other private motor vehicles (except buses) the same way. Fuel use in commercial trucks and other freight conveyances are modeled on the basis of freight tonne-kilometers, while private buses and other commercial passenger transport (including taxis) are modeled on a passenger-kilometer basis.

Among **passenger transport** modes, we assume that the fraction of passenger-kilometers traveled in mass transit and taxis[ddd] continues to decline, falling from over 41 percent in 1995 to just under 35 percent in 2010, rising slightly thereafter. Among the passenger transit modes, the fraction of total passenger-kilometers carried by all forms of public conveyance except air travel are assumed to continue to decrease. The fraction of taxis that are fueled with LPG is assumed to remain constant (at near 93 percent), the fraction of “private” buses that are diesel fueled is assumed to continue to slowly increase (from about 98 percent in 1995 to 98.5 percent in 2010), and the fraction of passenger rail traffic carried on electric (versus diesel) trains is assumed to become even more dominant.

We assume, in the BAU path, that the energy intensities (GJ per passenger-kilometer) of commercial autos (taxis) remain at 1995 levels until 2000 (energy intensities of taxis actually rose during 1990 to 1995), then decline at an average of 0.3 percent per year through 2020. The energy intensities of buses are assumed to continue to increase through 2000 (reflecting mostly a decrease in ridership), then remain constant. No change is assumed for the energy intensities of rail and air transport. The energy intensity of water-borne passenger transport (ferries) is assumed to increase (following recent trends—and probably again due to reduced ridership) through 2010.

Our model of changes in the numbers and usage of **private vehicles** starts with the estimate of the growth in the total number of private vehicles noted in section 6.3 of this chapter. Of the total stock of private road vehicles (including autos, trucks, motorcycles, and “bicycles with motors”), we assume that the fraction of diesel cars will continue to increase relatively rapidly (as in recent years) until 2020, but that growth in the number of diesel autos will slow over time (see Table 6-4). The fraction of vehicles that are gasoline autos will continue to grow slowly through 2010. The fraction of motorcycles in the private vehicle fleet is assumed to remain constant, but the fraction of “Bicycles with

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[ddd] By which we mean all passenger transport except in private cars.

Motors"[eee] is assumed to decrease relatively rapidly, following recent trends. The fraction of private gasoline trucks is also assumed to decrease, while the fraction of diesel trucks increases slowly until 2000, then remains constant.

Table 6-4: Assumptions for Changes in the Private Vehicle Fleet, BAU Path

			Growth Rate (%/yr) From			Implied Values for		
	1990	1995	95 - 2000	2000-2010	2010-2020	2000	2010	2020
Private Road Vehicles (except Buses)								
Fraction of Total Vehicles as:								
Gasoline Autos	43.98%	50.26%	0.756%	0.224%	-0.024%	52.190%	53.370%	53.244%
Diesel Autos	4.12%	6.19%	5%	3%	2%	7.905%	10.623%	12.949%
LPG Autos	0.081%	0.076%	0%	0%	0%	0.076%	0.076%	0.076%
Motorcycles	3.78%	3.83%	0%	0%	0%	3.828%	3.828%	3.828%
"Bicycles with Motors"	20.09%	15.42%	-3%	-2%	-1.50%	13.240%	10.818%	9.300%
Private Gasoline Trucks	20.94%	17.09%	-2%	-1%	-0.50%	15.445%	13.968%	13.285%
Private Diesel Trucks	6.98%	7.12%	0.50%	0%	0%	7.299%	7.299%	7.299%
Private LPG Trucks	0.022%	0.019%	0%	0%	0%	0.019%	0.019%	0.019%

We express the energy intensities of private vehicle use in GJ per vehicle-year. Note that this measurement combines two independent factors, namely the average energy intensities of the vehicles themselves (expressed, for example, in GJ per vehicle kilometer) and the average usage of each type of vehicle (expressed, for example, in kilometers traveled per vehicle-year). We assume that the GJ fuel used per vehicle-year in gasoline autos will not, on average, change between 1995 and 2020. This net zero change in intensity, however, could be interpreted either as A) an assumption of no change in either vehicle efficiency or vehicle usage, or B) as an assumption of slightly increasing vehicle efficiency (reduction in energy use per vehicle-kilometer) offset by an increase in vehicle usage. We assume that the energy intensity of diesel car use will increase (as per recent trends) through 2000, then remain constant. With the exception of private gasoline trucks, whose use is assumed to continue to be more energy intensive through 2010, all other private vehicles are assumed to show little or no change in fuel usage per vehicle year.

Among the modes for **freight transport** (excluding private trucks), we assume, in the business-as-usual path, that trucks and planes will continue to carry an increasing share of freight, and that trains and ships will carry proportionately less of the Japan's goods. By 2020, we assume that the fraction of total freight tonne-kilometers that are carried by trucks will increase to about 48 percent from 40 percent in 1995, and the fraction of freight tonne-kilometers decrease to about 38 percent from over 42 percent in 1995. We assume that the energy intensities of freight transport do not change, on average, between 1995 and 2020. Recent trends (1990 to 1995) have shown increasing freight transport intensities.

6.4.2. Energy Transformation (Fuel Supply) in the BAU path

In order to meet the demand for fuels implied by the changes in the demand sectors described above, we assume, in the BAU path, that the following changes take place in the Japanese fuel supply infrastructure.

[eee] We assume that these are mostly motorcycles with small displacement engines and pedals, also called "Mopeds" in the United States.

Electricity transmission and distribution losses are assumed to decline to 4.5 percent by 2020, and losses in transmission and distribution of gas are assumed to fall to 0.2 percent (down from 5.86 percent and 0.34 percent in 1995, respectively). Both changes result from technological improvements and ongoing replacement and refurbishing of old equipment and lines.

In the BAU path, it is assumed that new nuclear power plants will be phased in as per the USDOE EIA[fff] "Low" or "Reference" estimates for timing of units "in the construction pipeline[ggg]", and that existing nuclear plants will be phased out as they reach 40 years old[hhh]. The total nuclear capacity added between 1995 and 2020 is thus assumed to be about 12.5 GW—slightly less than the total existing nuclear generating capacity retired by 2020. We make no explicit assumption about the use of mixed oxide (MOx—a mixture of Plutonium and Uranium oxides recycled from spent nuclear fuel) fuel in reactors in Japan, but the BAU path could include the limited use of MOx fuels, mostly to consume existing inventories of reprocessed fuel. Generating capacity of other types of power plants is added over time so as to maintain a reserve margin in the 20 percent range (down from about 41 percent in 1990[iii]) for the period from about 2008 on. The types and amounts of (non-nuclear) generating capacity we assume are added between 2000 and 2020 are:

- Pumped-storage hydroelectric plants (about 6 GW added);
- Standard coal-steam plants (20 GW added);
- Natural gas steam plants (19 GW added);
- Natural gas-fired combined-cycles plants (22.5 GW added); and
- Oil-fired combined-cycles plants (16 GW added).

We further assume that refurbishing or repowering of hydroelectric or fossil-fueled generating facilities existing as of 1995 allows these facilities to continue to operate through 2020.

Changes in municipal gas production include shifts to feedstocks that has less indigenous natural gas and more imported LNG relative to 1990. Oil refining capacity is assumed to remain at approximately 1997 levels through 2020. This assumption is based on the current status of Japanese refining (inefficient and high-cost relative to competitors in the region), and means that the export/import balance for oil products will shift toward greater imports over the for the projection period[jjj]. Natural gas, crude oil, and coal extraction capacity in Japan are assumed to remain at approximately their 1995 levels through 2020.

[fff] US Department of Energy, Energy Information Administration (USDOE EIA, 1996), Nuclear Power Generation and Fuel Cycle Report, 1996. Report DOE/EIA-0436(96), October 1996. USDOE, Washington, DC, USA.

[ggg] Units either already under construction (as of the end of 1995) or considered to be well along in planning for construction.

[hhh] This assumption is a guess on our part, but one that we can (and will, at our earliest convenience) check with Japanese collaborators. Retirement dates for U.S. plants built in the early 1970's appear to be about 40 years after the date of first operation.

[iii] Note that when we refer to "reserve margin", we refer to the amount by which total generating capacity exceeds the annual peak load. This relatively crude definition does not take into account factors such as the unavailability of plants due to maintenance or lack of resources (such as low river levels) that may coincide with peaks in demand, thus others' figures for reserve margin in Japan may appear different (generally lower) than ours.

[jjj] This assumption about the future of the Japanese refining industry is based upon a conversation with David Fridley of Lawrence Berkeley National Laboratory (5/20/98). The Japanese refining industry has long been protected by various trade and economic policies that are now being substantially revised. Given the high production costs and relatively inefficient operation of Japanese refineries, it seems likely, based on the current impetus toward deregulation in Japan,

6.4.3. Measures to address energy supply risks in the BAU path

In addition to the more quantitative elements of the Business-as-Usual path described above, measures will be taken, either implicitly or explicitly, to manage various types of risk. Among these risks, as noted earlier in this report, are "Energy Supply Risks", including the risks of being short of supply of a key energy source (fuel) and the risks inherent on relying on a particular energy technology/fuel pair (or set of pairs). Some of the measures to reduce energy supply risks that we assume would be consistent with the BAU path include:

- **Diversify the types of fossil fuels used**: This is included in the BAU path with the continued shift toward use of more gas-fired end-use devices, as well as the increased use of both gas and coal in for electricity generation.
- **Use proven technologies**: One way to avoid the risks inherent in reliance on any particular fuel and technology is to primarily use technologies that are well-proven or represent a limited, safe departure from technologies for fuel supply and utilization that are already widely in use. In a BAU path, it seems likely that there will be little price-related pressure to increase the efficiency of new devices, so most research and development effort may in fact be focused on refining existing technologies, rather than innovations in new directions[kkk].
- **Diversify sources of fossil fuel supply**: In the BAU path, diversification in the sources of fossil fuel supply used by Japan might include working with new potential new oil suppliers such as Russia, North Korea (if touted oil reservoirs offshore of the DPRK come to fruition), and others further afield (the Caspian region, for example) to reduce the relative dependence of Japan on Middle East oil. By the same token, a drive toward diversification in LNG and natural gas sources would lead Japan to press for and help to underwrite agreements on regional pipeline (or pipeline/LNG terminal) systems that could supply Japan, as well as new LNG facilities in Northeast Asia and other areas. Diversification in sources of coal might lead Japan to assist with infrastructural development in the Russian Far East, and to contract for deliveries from the United States and Canada, as well as from Australia (its current primary supplier).
- **Diversify sources of supply of nuclear fuels**: Natural uranium is available from a number of suppliers, ranging from the United States and Canada to Russia, France, Namibia, South Africa, Niger, Kazakstan and Uzbekistan. Japan's procurement patterns already appear to be fairly well diversified among the world's suppliers[16]. Continued investment and technical assistance to uranium producer nations, where required, should allow Japan to maintain its diversity of supply. Japan could even secure domestic supplies of uranium by moving forward with its research and development on extraction of uranium from sea water[17], although we do not assume that such production will play a large role in Japanese uranium supply by 2020. Japan is, however, largely dependent on other nations for enrichment services. In the BAU case, we assume that Japan adds to

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that relatively little expansion will occur at Japanese refineries in the foreseeable future (although refinery upgrades to produce, for example, less-polluting motor fuels are likely). As a result, any increase in domestic demand for refined products is likely to be met through increased imports from other refineries in Asia (particularly the Republic of Korea and Singapore) and elsewhere.

[kkk] Of course, environmental, social, and other considerations unrelated to the economics of fuel consumption will may still provide a drive toward higher energy efficiency, even in the BAU case.

its own enrichment capacity, and possibly forges technical alliances for investment in enrichment facilities in Russia, in addition to continuing to contract with US and European providers of enrichment services.

- **Add to fuel stockpiles (fossil and nuclear)**: Japan already holds a substantial stockpile of oil and oil products—larger, in fact than IEA guideline call for. These stockpiles will need to be expanded somewhat as the use of petroleum products increases in the BAU case, but our assumption is that the number of days of average supply remains present in the oil stockpile remains unchanged. We assume, in the BAU case, that Japan also builds up a stockpile of nuclear fuel, including both enriched and natural uranium, amounting to 5 and 25 years of uranium consumption (based on the current rate of fuel consumption in Japanese reactors).
- **Create or enhance multi-fuel capabilities in key industries and infrastructure**: A set of measures that would allow fuel types to be readily more readily substituted in Japan would help to reduce the impact of a physical interruption in supply (or shortage) of any one fuel type. Measures such as retrofitting boilers and furnaces in key industries for use with either oil or gas fuels, or building new power generation facilities (such as combined-cycle plants) with the capability to relatively quickly switch from one fuel to another, are technologically straightforward means of providing insurance, in a BAU path, against fuel supply disruptions.

6.4.4. Measures to address economic risks in the BAU path

Apart from and addition to the risks of physical shortages in supply, or to the risks of failure of a particular technology, are the risks of economic damage that such shortages or failures might precipitate. Economic damage could accrue, for example, from the necessity of paying suddenly higher fuel prices, or from lost productivity due to fuel shortages or technology failure. Measures we assume would be used mitigate, minimize, or spread these types of economic risks under a Business-as-Usual scenario might include:

- **Add to fuel stockpiles (fossil and nuclear)**: We assume, in the BAU case, that stockpiles of crude oil and oil products are maintained at the 1995 fraction of total annual demand.
- **Purchase insurance against production outages**: Firms could purchase insurance that would reimburse them for lost production due to fuel supply shortages, or for economic losses sustained by higher prices[lll].
- **Invest in commodity futures or long-term contracts**: The Japanese government and/or individual large-scale fuel buyers could structure a portion of their fuel buying so as to secure a stable longer-term price, either through long-term contracts or by investment in options to buy a given quantity of a given fuel at a given price on a given future date (commodity futures). We assume that in the absence of a major fuel shortage, use of futures and long-term contracts as price insurance results in Japan paying roughly five percent more for its fuel, on average, than it would if all fuel were purchased on a spot market basis.
- **Diversify fuel supplies and pursue multi-fuel capabilities**

[lll] Whether the finance and insurance industry would be interested in offering such a product—particularly in that payment of damages, when they occur, will likely tend to be on a broad scale (due to the national/global nature of energy markets)—is not clear.

- **Encourage greater participation in energy markets by private sector actors**: In an effort to diversify risk within the Japanese economy, we assume that the BAU path includes inducements—in the form of regulatory reform, opening of the economy to additional outside investment in Japanese energy infrastructure, and other policy changes—for private sector actors to take more of a role in securing fuel supplies and in creating and running energy infrastructure for the Japanese economy. This enhanced participation by those outside the government would help to diversify the risks of economic damage due to rapid price changes or supply disruptions, possibly resulting in reduced economic risks to particular sectors of the Japanese economy.

6.4.5. Measures to address technological risks in the BAU path

The technological risks involved in any given energy path include the risks of relying on a particular technology, or on a particular line of technological research and development, to meet a substantial fraction of energy needs, either now or in the future. Among the approaches for mitigating technological risks that would likely be included in a BAU path are:

- **Retain research efforts on multiple technical approaches for key technologies**: For example, a BAU path would likely include retaining research programs on different nuclear power reactor designs and fuel cycles. We assume under that the BAU path will include reprocessing of nuclear fuel at modest levels, and will also include research and development on other types of nuclear waste management. The BAU path is also assumed to retain R&D programs for renewable energy technologies, at approximately the current level of effort.
- **Rely primarily on proven technologies**: Proven, already commercialized technologies are less likely to fail in a generic way. The BAU path relies primarily on existing technologies.
- **Develop back-up capabilities for technologies that could become bottlenecks if they fail**
- **Adopt technologies that can be implemented more quickly**: This would include continuing the development of manufacturing capability for smaller, modular technologies for fossil fuel use and (perhaps further in the future) nuclear reactor components.

6.4.6. Measures to address environmental risks in the BAU path

As has been noted earlier in this report, we believe that environmental risks, and the management thereof, will increasingly affect the direction of development of the energy sector. In the Business-as-Usual path we assume that environmental risks are addressed via:

- **Adoption of pollution-control technologies on new and existing equipment**: We assume that the best available technologies for controlling emissions of sulfur and nitrogen oxides from power plants and other large combustion equipment are installed throughout Japan by 2020. In addition, we assume that home and commercial-sector gas appliances with low-NO_x burners achieve substantial penetration by 2020, and that NO_x emissions per vehicle kilometer for road vehicles also continue to decrease.
- **Develop and apply remediation techniques to polluted areas**

- **Export polluting industries**: One of the trends in industrialized nations has been to export heavy industries to countries where fuels and labor may be less expensive and/or where environmental standards are not as stringent. In the BAU case, we assume that this trend is implicit in the ongoing reduction in production in subsectors such as mining and quarrying, iron and steel, and textiles and fiber in Japan.
- **Develop plans for responding to impacts of climate change and other heightened environmental risks**: In the BAU case, plans would be made for reinforcing of sea walls and dikes, rebuilding beaches damaged by higher tidal surges, adopting special maintenance techniques for structures (and perhaps even ecosystems) to reduce the impacts of acid rain and other air pollution, and a host of other approaches designed to fend off the impacts of ongoing environmental degradation. In the BAU case, these plans would be subject to analysis of their relative costs and benefits before they are implemented.

6.4.7. Measures to address socio-cultural risks in the BAU path

Along with the economic and environmental risks associated with a particular energy path also come a set of risks that we have termed "socio-cultural" risks. Socio-cultural risks include risks of political conflict (domestic and/or international) over energy resources, energy technologies, or the economic or environmental impacts of energy systems. We assume that measures taken to reduce socio-cultural risks in the BAU path would include

- **Maintain (or increase) control over sensitive information**: Continuing on a Business-as-Usual path may imply continuing to tightly restrict access potentially sensitive or controversial technical or environmental information about key technologies.
- **Steer clear of sensitive locations, groups, and technologies**: Judiciously plan the development and management of elements of the energy system that could cause controversy so as to avoid siting noxious or potentially dangerous facilities in cultural or recreational areas (for example), anticipate and avoid initiatives likely to be objectionable to key political groups, and avoid use of technologies that bear a social stigma.
- **Provide compensation to host communities** in order to better match the benefits and impacts of energy facilities.

6.4.8. Measures to address military-security risks in the BAU path

As the energy system of a society is part of the foundation on which the society rests, there are inevitably security issues with military implications involved in maintaining the energy system. We assume that in Japan, under the BAU path, the following military measures are taken in order to enhance energy security in the broad sense:

- **Increase military preparedness to counter possible outside threat or terrorism**.
- **Increase security to guard nuclear materials**, including materials in transit at sea.
- **Increase military presence in the region,** including a more pronounced naval presence in sea lanes through which oil, gas, coal, and nuclear materials are shipped.

- **Seek military agreements with neighboring states and others** in order to reduce tensions and establish protocols for military cooperation and handling of incidents.
- **Seek agreements on handling of nuclear fuels/wastes with other nations**, which would likely include the establishment of an "Asiatom"-type[mmm] organization for sharing of nuclear information and facilities.

6.5. Description of Assumptions for "Alternative" Path Through 2020

Our "Alternative" path for the development of the Japanese energy sector between 1995 and 2020 features—relative to the BAU path—very aggressive energy efficiency measures in all demand sectors (and in electricity generation), an emphasis on the use of advanced technologies available for emissions reduction and environmental protection, accelerated implementation of renewable fuels, and large-scale fuel switching to municipal gas (mostly LNG) for many end-uses. In many cases, our assumptions for the demand- and supply-side measures incorporated into the Alternative path are derived (or roughly extrapolated) from elements of the "WWF Case" (or "Intervention Case"[nnn]) as assembled for the study Key Technology Policies to Reduce CO_2 Emissions in Japan: An Indicative Survey for 2005 and 2010, produced by the Japan office of the World Wide Fund for Nature[18]. Note that we do not claim that the Alternative path is explicitly designed to be "optimal" in any particular respect. Like the WWF Case on which is has been based, it is designed to be an indicative counterpoint to the Business-As-Usual path, demonstrating what sorts of measures one might apply to move toward and energy system with fewer environmental impacts.

6.5.1. Energy Demand in the Alternative path

Our approach in laying out an indicative Alternative path for the evolution of energy demand in Japan is to apply a number of different measures—some purely technological in nature, some purely policy-derived, and most a mixture of technology and policy—to specific end-uses in each sector of the Japanese energy system. Our assumptions for the Alternative path, to the extent that they vary from assumptions in the BAU path, are described below.

HOUSEHOLD SECTOR

For the household sector we assume that the Alternative path includes a variety of energy-efficiency technologies, with some fuel-switching to natural gas and use of solar energy. In many cases, our assumptions are derived or extrapolated from those presented in the WWF-Japan report. Some of our key assumptions, sorted by end-use, are described below.

- For home **cooling**, we assume that higher-than-standard efficiency room and central air conditioners are phased in starting in approximately 1998, with 90 percent of cooling appliances being of the

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[mmm] See, for example, Atsuyuki Suzuki (1996), A Proposal on International Collaboration with Nuclear Power Development in East Asia,; and Jor-Shan Choi (1996), An East Asian Regional Compact for the Peaceful Use of Nuclear Energy, both prepared for the Energy Workshop of the Northeast Asia Cooperation Dialogue V, Institute of Foreign Affairs and National Security, Seoul, Korea, September 11-12, 1996.

[nnn] The WWF Case is a modified form of the "Intervention Case" of the Asia-Pacific Integrated Model (AIM) for Japan.

higher-efficiency type by 2010, and 100 percent by 2020. In addition, we assume that high-efficiency cooling devices are on average 20 percent[ooo] less energy intensive than standard devices by 2000, and that their average energy intensities continue to decrease at 0.5 percent per year between 2000 and 2020.

- In the home **space heating** end-use, we assume that the percentage of homes using non-electric heating fuels that heat with city gas increases to 45 percent by 2020, with an offsetting decrease in the fraction of dwellings that use kerosene as a main heating fuel. The average intensity of gas-fired space heating devices (furnaces and boilers) is assumed to decrease at 0.5 percent per year. Electric heat pumps used for heating and cooling are assumed to follow the same energy intensity trends as air conditioning units.
- Another key assumption from the WWF-Japan study, one with ramifications for both space heating and space cooling, is an aggressive program of improvement in the insulation levels in Japanese homes, coupled with other building envelope measures for dwellings. Following the assumptions in the WWF report, we assume that 25 percent and 40 percent of dwellings are heavily insulated by 2010 and 2020, respectively. The effect of the improvements in insulation and other measures is assumed to reduce heating and cooling energy intensities by 30 percent in those homes where it is applied.
- In the **cooking** end-use, the major change from the BAU path is that gas cooking is assumed to be used by progressively more households over time—consistent with increased penetration of gas as a household fuel for space heating and water heating. We assume that city gas will be used for cooking in 65 percent of homes by 2020, displacing LPG cooking and cooking with kerosene.
- For **hot water heating**, we again assume increased penetration of city gas use, with 55 percent of households using gas water heat by 2020. We also assume that the use of condensing (or "latent heat recovery")-type water heaters increases to comprise 19 percent of all water heaters in 2010, and 40 percent in 2020. This technology is assumed to be applied in homes using city gas or LPG water heat. The penetration of solar water heaters is assumed to increase from approximately 11 percent in 1995 to 15 percent in 2010 and 25 percent in 2020. The increase in solar and city gas water heating reduces the use of kerosene and LPG water heat. We assume that the fraction of water heat provided by electric units does not change, but that 25 percent of water heaters are of the heat-pump type (with an average energy intensity approximately one-third of that of resistance water heaters) by 2020.
- In the **lighting** end-use, we assume, consistent with assumptions in the WWF-Japan report, that roughly 80 percent of the lighting provided by incandescent bulbs in 1995 is replaced by compact fluorescent light bulbs (CFLs) or other luminaire/bulb combinations with similar efficiency by 2010, increasing to 90 percent by 2020. We also assume that a combination of improvements in residential lighting technologies—including better placement of lighting, more efficient fluorescent bulbs, better reflectors, and broader use of occupancy sensors that turn off lights when rooms are empty—combine to decrease the overall use of electricity for lighting per dwelling by 30 percent relative to 1995 (in addition to savings from switching from incandescent lighting).
- For **refrigeration**, it is assumed that refrigerators with average energy intensities that are a factor of 2.2 lower than 1995 models comprise about 80 percent of the refrigerator stock by 2010, with a further improvement in efficiency in following years.

[ooo] This is a rough estimate only, and should be confirmed.

- We assume that electricity use per appliances by **fans, clothes washers and dryers, and vacuums** decreases by 0.5 percent per year relative to the BAU case as more efficient motors and other electricity-saving improvements are incorporated into these items.
- The WWF-Japan report assumes that **television sets** with LCD (liquid-crystal display) screens start to come into use after 2000. LCD monitors for desktop computer systems are already available now (1998). We assume, based roughly on WWF-Japan figures, that LCD-type televisions constitute roughly 3 percent of the TV sets in Japan by 2010, increasing to about 30 percent by 2020. LCD TV sets are assumed to use roughly 20 percent as much energy as standard (cathode ray tube-based) sets for units with similar viewing areas[ppp].
- For **other appliances** as well as for microwave ovens, televisions, and air conditioners, we assume that the estimate of potential for reducing stand-by mode electricity consumption proposed in the WWF-Japan report can be realized, namely that the equivalent of 10 percent of total household electricity use, relative to the BAU case, can be saved by 2010 via the elimination or significant reduction of electricity used by appliances (for clocks, or to enable "instant-on" features, for example) when those appliances are not actively in use[qqq]. We assume that by 2020 savings in standby mode use, coupled with other policy-driven efficiency improvements in consumer appliances beyond those listed individually above, reduce household electricity consumption by the equivalent of 20 percent of total electricity use in the BAU case.
- In addition to the above, the WWF-Japan report includes large-scale introduction of **solar photovoltaic panels** mounted on residences. The total capacity of panels installed by 2010 is taken to be 2,160 MW (as assumed by WWF-Japan), which we assume to increase to 6,000 MW by 2020. Note that though these panels will likely be providing power directly to the residence to which they are attached (as well as, in many instances, sending power back to the electric grid), we have modeled them as supply-side, rather than end-use measures.

COMMERCIAL/PUBLIC/SERVICES SECTOR

In the Commercial, Public Buildings, and Services sectors of the Japanese economy, many opportunities exist for improving energy efficiency. As we have in the residential sector, we have included technologies suggested in the WWF-Japan report as part of the Alternative path. The end-use technologies that we assume are adopted include:

- High performance furnaces and boilers for **space heating**, and probably some water heating and process heat as well (depending on the subsector). The WWF report lists a total savings through the use of high performance furnaces of 4.0 billion liters of oil equivalent by 2010, which is equal to about 16 percent of BAU-case consumption of coke, kerosene, heavy oil "A", and heavy oil "C", which we assume are the main fuels used in furnaces and boilers in the commercial sector. We assume that continued improvements in furnace designs increase the savings relative to the base case to 25 percent by 2020.

[ppp] Estimate based on current ratio of power demand by LCD and CRT computer monitors as quoted in PC TODAY PROCESSOR, "Looking Behind the Screen (Cont'd)", from http://www.pc-today.com/editorial/features/970132c.html, visited 3/24/98.

[qqq] The WWF-Japan report (page 16 of the English version) cites as an example the stand-by mode consumption of electricity by audio equipment, in which electricity consumption when the equipment is not "in use" adds up, over a year to nearly twice the energy used during the hour per day when the equipment is "in use".

- In addition, for **space and water heating**, as well as for process heat, we assume that the share of natural gas among non-electric fuels used in the sector rises from a bit over 10 percent in 1995 to 25 percent by 2010 and 40 percent in 2020, with a corresponding decline in the use of fuel oils. Also for space and water heating, we assume that "latent heat recovery-type" boilers fired with city gas and with LPG displace 30 percent of standard boilers by 2010, replace 60 percent of standard boilers by 2020, and use 10 percent less fuel per unit of heat output than standard units. By 2010, accelerated introduction of cogeneration reduces overall use of non-electric space and water heating fuels by about 1.2 percent relative to the BAU path. Another roughly 2.4 percent of total non-electric fuel is saved via the introduction of waste heat water heaters. A final 1.5 percent fuel savings in overall non-electric fuel consumption in 2010 is achieved by improvements in building insulation and other improvements in building envelope efficiency. We assume that savings from cogeneration, waste heat water heaters, and building envelope improvements double, relative to those achieved in 2010, by 2020.
- For space **cooling**, we assume that the introduction of new high-efficiency electric HVAC equipment, with efficiency approximately 10 percent higher than standard efficiency units, capture 6 percent of the market by 2010, and 20 percent by 2020. In addition, gas-fired heat pumps are assumed to serve 15 percent of the commercial sector cooling market by 2010, and 25 percent by 2020. Additional cooling energy is saved through the building envelope improvements noted above (assumed to save 1.5 percent of electricity for space cooling by 2010).
- For **lighting and plug loads**, we assume, based on analysis in the WWF-Japan report, that a combination of reduction in stand-by mode energy consumption by office machines, improvements in refrigeration and lighting in vending machines, other refrigeration upgrades, and lighting improvements (including improved lighting controls, efficient exit lights, and improved fluorescent bulbs) together save roughly 18 percent of electricity used for lighting and plug loads in the BAU case[rrr].
- Large-scale introduction of **solar photovoltaic panels** in commercial installations is also included in the WWF report. The total capacity of panels installed by 2010 is taken to be 1,690 MW (as assumed by WWF-Japan), which we assume to increase to 5,000 MW by 2020. Though these panels will likely be providing power directly to the business to which they are attached (as well as, in many instances, sending power back to the electric grid), we have, as with the residential sector, modeled them as supply-side, rather than end-use measures[sss].

INDUSTRIAL SECTOR

In the industrial sector, the WWF-Japan report (and the underlying AIM/End-use model) assumes that a variety of specific efficiency-improving technologies will be implemented in four major subsectors (iron and steel, cement, petrochemicals, and paper and pulp) that consume the majority of the fuels used in industry in Japan. Additional generic technologies are applied in other industrial subsectors. Our assumptions for changes in energy use in the Alternative path are described briefly below.

[rrr] By our estimate (as derived from data provided by the International Energy Studies Group of Lawrence Berkeley National Laboratory), lighting and plug loads constituted about 87 percent of total electricity use in the commercial sector as of 1995.

[sss] The values cited in the WWF-Japan report for the output of photovoltaic panels installed in commercial-sector applications imply an average annual capacity factor of about 15.5 percent.

- Overall, the assumption in the WWF-Japan report appears to be that the three of the four major industrial subsectors (iron and steel, paper and pulp, and petrochemicals) listed above meet the "Keidanren Voluntary Action Program" target of reducing energy use per unit of output (tonnes of steel or cement, for example) by 10 percent (relative to 1995 levels) by the year 2010. We assume that the cement/ceramics subsector also meets that target, that continued efforts result in a total 20 percent decrease in energy intensity by 2020, and that the energy savings apply equally to all fuel types.
- The WWF-Japan report also includes introduction of **high-performance industrial furnaces** in (apparently) all industrial subsectors. Savings from implementing the high-performance furnace is estimated (in the WWF-Japan report) at 18 billion liters of oil equivalent, which is about 13 percent of year-2010 non-electric fuel use in our BAU case. We assume that savings from application of high-performance furnaces and/or **boiler improvements and combustion controls** in each industrial subsector saves an average of 13 percent of total non-electric fuel use in 2010, and 20 percent by 2020. These savings are assumed to be in addition to the savings achieved in the four major subsectors using subsector-specific technologies.
- Another generic technology, which we assume applies to all industrial subsectors except for the four major subsectors, is high-efficiency **electric motors and electronic motor controls**. We assume that implementation of these devices, plus **other improvements in the efficiency of electricity use** (lighting and electronic equipment improvements, for example) reduce the intensity of electricity use by 10 percent by 2010 relative to BAU assumptions, with savings increasing to 20 percent by 2020.
- As in other sectors, we assume that the Alternative path will include an accelerated (relative to the BAU path) shift toward the use of municipal gas (mostly derived from LNG) as a fuel in industry, displacing primarily heavy oil products.

AGRICULTURAL/FISHERIES/FORESTRY SECTOR

Almost all of the energy used in the agricultural, fisheries, and forestry sector is in the form of oil fuels (primarily kerosene, diesel fuel, and heavy oil "A"). Unfortunately, we do not yet have a breakdown of how these fuels are used, although they are probably primarily used as motor fuels, with perhaps some use in boilers and drying equipment. Lacking end-use breakdowns, and taking into account the relatively limited energy consumption in the sector, we have not assumed specific energy efficiency measures to address oil use in the Alternative case[ttt]. We assume that most of the electricity consumption in the sector is used in electric motors, and thus motor and drive improvements like those listed above for the industrial sector (10 percent by 2010 relative to BAU energy intensities, with savings increasing to 20 percent by 2020) will apply.

TRANSPORT SECTOR

The transport-sector measures that are part of the Alternative path—derived in large part, as noted, from the WWF-Japan study—include both improved and more efficient technologies in existing

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[ttt] It is likely measures such as boiler improvements/controls and higher-efficiency diesel engines could probably be applied in the agricultural/fisheries/forestry sector, but we do not yet have enough information to estimate the degree to which these technologies might be useful or the speed with which they might be adopted.

transport modes, plus some "mode-shifting"—moving passengers or freight from one type of transport to another. Assumptions as to technological improvements in the transport sector include:

- **Introduction of "hybrid" cars**: Hybrid automotive technologies typically use an electric motor (or set of motors) to drive the wheels of the vehicle, while an internal combustion engine (or even fuel cells or combustion turbines, in future models) uses gasoline, diesel, natural gas, hydrogen, or another suitable fuel to generate power, which is stored in a small battery when not needed to drive the vehicle. Optimization of the engine's size and speed, plus vehicle improvements such as regenerative braking[uuu], modifications in vehicle bodies and finish to lower wind resistance, lower-friction tires, lighter materials, and other innovations allow hybrid cars and similar technologies to deliver similar levels of speed, carrying capacity, comfort, and safety, while using much less fuel and producing substantially fewer emissions. Toyota and other Japanese auto companies are already starting to produce first-generation hybrid vehicles. Our assumptions for the introduction of new vehicles for private transport, for commercial passenger transport, and for goods transport, are detailed in Attachment Set D. Generally, we assume (as does the WWF-Japan study) that hybrid passenger vehicles start to be introduced by the year 2000, and dominate the private auto market by 2010. This rapid introduction necessarily assumes either policies (taxes, regulations, or a combination) to hasten the introduction and production of hybrid vehicles in Japan. The speed of introduction is hardly out of the question, however, as the Japanese automobile stock turns over quite rapidly—in part due to favorable tax treatment for newer vehicles. We also assume that compressed natural gas (CNG) will begin to be used as an automotive fuel by 2000 in some subsectors, supplying up to 10 percent of private cars and trucks by the year 2020. As in the WWF-Japan report, we assume that the energy intensities of hybrid cars are less than half those in today's autos[vvv], and that efficiencies continue to improve through 2020.
- **"Hypercars™"**: An advanced form of the hybrid car, dubbed the "**hypercar™**", has been touted by the Amory Lovins and his colleagues at the Rocky Mountain Institute[www]. Hypercars™, made substantially of carbon-reinforced polymers, would be much lighter and more aerodynamic than current vehicles. Advanced models, Lovins and his colleagues claim, could be up to 10-fold more efficient than existing cars of the same size. After 2010, we assume that more efficient hybrid vehicles (the "hypercars™") start to be introduced in large numbers. We assume that CNG-fueled hypercars™ are introduced starting before 2010, and hydrogen-fueled hypercars™ begin to be used by the year 2015. We assume that the energy intensities of the first hypercars™ introduced are about 2.6 liters (of gasoline equivalent)/100 km (0.87 GJ/1000 vehicle-km), decreasing to 1.5 liters/100 km by 2020.
- **Hybrid Trucks and Buses**: We assume that hybrid vehicles penetrate the market for trucks and buses more slowly than for cars (due in part to the typically longer life of heavier vehicles), but still constitute over a third of those vehicle classes by the year 2010. CNG-fueled hybrid trucks and buses are assumed to be introduced starting in 2000, with CNG vehicles capturing roughly 10

[uuu] In regenerative braking, the energy in the vehicle's forward motion is captured (in part) by a generator, which produces power to charge a battery. The brakes in today's standard automobiles dissipate the energy of the moving vehicle as heat (and occasionally noise) in bringing the vehicle to a stop.

[vvv] The WWF-Japan report bases their hybrid car intensity estimates on a car with a 1500 cc engine getting 14 kilometers per liter of gasoline, as do we. Our estimate of the average efficiency of gasoline-fueled cars in Japan in 1995 is somewhat lower, at approximately 9.5 km per liter.

[www] See, for example, A.B. Lovins, M.M. Brylawski, D.R. Cramer, and T.C. Moore (1996), Hypercars™: Materials, Manufacturing, and Policy Implications. Rocky Mountain Institute, Snowmass, CO, USA. March, 1996.

percent of the truck and bus market by 2020. We assume that the energy intensities of hybrid trucks and buses (including private hybrid trucks) decline by a factor of 1.2[xxx] in 2000 relative to standard 1995 efficiencies, and that the intensities of hybrid trucks and buses in the year 2020 is a factor of 2 less than in 1995.

- **Other Transport Modes**: For lack of ready access to data, we have not yet assumed significant improvements in efficiency in other transport modes under the Alternative scenario. Improvements in aircraft efficiency[yyy], enhancements in drive systems and other improvements for electric trains[zzz], and improved ship designs are all technologies worth exploring for the future.

In addition to vehicle efficiency improvements, fuel can be saved by moving passengers or freight to transport modes that are more efficient, by improving the efficiency with which freight is handled, and by changing ways in which office work is done so that less passenger travel is required. We assume the following changes, driven by policy initiatives, take place in the way that goods and people travel in the Japanese transport sector.

- There is a shift in passenger traffic **from private automobiles to trains and commercial buses**.
- There is a shift in freight transport **from road vehicles to trains and ships**
- The expanded use of **tele-commuting** from home offices or satellite offices reduces both rail and auto passenger travel
- The use of **video conferencing** from local centers reduces auto, rail, and air passenger travel.
- Improvements in freight management, including improved loading techniques and wireless communications, allow the average efficiency of freight transport by "mini" trucks to increase by 0.8 percent by 2010, and by 1.6 percent by 2020. Similar improvements for larger commercial trucks increase the average efficiency of freight transport by 0.3 percent by 2010, and by 0.6 percent by 2020.

Our assumptions as to the volume of public transport and freight traffic shifted are provided in Tables 6-5 and 6-6. Tele-commuting is assumed to reduce private auto transport as well, which we have modeled as a reduction in the total fuel use per private car.

Table 6-5: Passenger Traffic Impacts of Mode-Shifting and Other Measures

	2000	2010	2020
Total Passenger-km before Mode Shifting and other measures (Billion Pass-km, including private cars/cycles)	1,546	1,836	1,997
Billion Pass-km removed FROM rail via telecommuting	2.4	23.7	77.3
Billion Pass-km removed FROM rail via video conferencing	1.0	10.2	20.3
Billion Pass-km removed FROM planes via video conferencing	1.3	13.5	27.0
Billion Pass-km shifted TO rail from passenger cars	4.6	18.3	59.5
Billion Pass-km shifted TO comm'l buses from pass. cars	1.6	5.5	17.9

[xxx] That is, the assumed intensity for hybrid trucks in 2000 is equal to the average intensity in 1995 divided by 1.2.

[yyy] As Japan is not currently a major manufacturer of large aircraft, efficiency improvements in aircraft used in Japan will likely be a function of improvements made in the aircraft industries of the United States and of Europe.

[zzz] One would think, for example, that regenerative braking (perhaps even generation back to the grid?) would be an attractive option for train drive systems.

Table 6-6: Freight Traffic Impacts of Mode-Shifting

	2000	2010	2020
Total tonne-km before Mode Shifting (Billion tonne-km, including private trucks)	580	619	651
Billion tonne-km shifted TO rail from trucks	8.05	11.60	34.80
Billion tonne-km shifted TO water freight from trucks	3.48	5.46	16.37

Although it is beyond the scope of this paper to suggest, in a detailed way, policies that might be used to bring about the changes in traffic patterns that we assume, options might include:

- Higher taxes on private vehicle use
- Subsidies and incentives for companies that allow their employees to work from home or from satellite offices
- Improvements in mass transit that make commuting via rail and bus easier, quicker, more comfortable, and less costly. These might include building new rail lines and terminals, expanding the use of bus-only lanes on streets and highways, and further subsidization of mass transit
- Subsidization of video conferencing facilities (at least at first), and accelerated efforts to make video conferencing less complex (for example, by encouraging developers of video conferencing technologies to agree on standards)
- Building infrastructure that allow expanded use of ships and trains for shipping of goods

6.5.2. Energy Transformation (Fuel Supply) in the Alternative path

We assume four major types of differences between the energy transformation sectors in the Alternative and Business-as-Usual paths:

1. Some supply infrastructure can be reduced in capacity in the Alternative path (or growth in capacity is less than in the BAU case) due to lower demand for fuels.
2. Refurbishing of existing fossil-fueled power plants and other infrastructure is accelerated, increasing efficiency and lowering emissions.
3. The implementation of the use of renewable fuels and resources, particularly in electricity generation, is accelerated, as is the use of LNG.
4. Pollution control equipment is added to existing power plants at an accelerated rate, and new power plants and other transformation facilities are constructed to strict environmental standards.

Specific assumptions for fuel supply system changes in the Alternative path, some taken from elements of the WWF-Japan report, include:

- Increased electricity generation fired with municipal solid wastes (MSW), other biomass wastes, or landfill gas from roughly 2,000 MW in 1995 to 4,000 MW in 2010 and 5,500 MW by 2020.
- Repowering or extensive refurbishing of half of the existing (remaining after accelerated retirement) stock of oil-, and gas-fired steam-cycle generating plants by 2010, and 75 percent of the plants by

2020. Repowering and refurbishing is assumed to raise the gross efficiency of power generation by an average of 4 percentage points.

- In addition to the photovoltaic panels installed on homes and businesses, the Alternative path assumes that a breakthrough in photovoltaic (PV) costs occurs and allows extensive use of PV power by utilities (or private power developers). Total PV capacity in utility applications is assumed to be 3,000 MW by 2010, and 14,000 MW by 2020.
- A major gas pipeline, with a capacity of 20 billion cubic meters per year**,** is assumed to be completed by 2008. This pipeline will take gas from Russia's Sakhalin Island to an area near Tokyo. A second, unspecified pipeline from Siberia or the Russian Far East to Japan is assumed to be completed in 2015, and is assumed to be capable of carrying 30 billion cubic meters of gas per day.
- New gas- or oil-fired cogeneration located on the premises of industrial and large commercial/public sector installations totals 13,000 MW by 2010 and 22,000 MW by 2020. By 2020, approximately 40 percent of this capacity is assumed to be gas-fired fuel cells.
- Starting in about 2010, imports of hydrogen gas produced in (for example) Australia are assumed to begin to meet about half of hydrogen fuel requirements by hypercars™. Domestic hydrogen production (from electrolysis of water) is assumed to meet the other half of demand.
- No new oil refining capacity is added after 2000, but existing refineries are assumed to be run at a sufficient level to meet domestic requirements for diesel and jet fuel. Excess production is assumed to be exported to other nations in the region (particularly China).
- Wind power is added to a total capacity of 5,500 MW by 2010 and 22,000 MW by 2020. Some of this capacity may well be located in offshore areas.
- As a result of end-use measures and accelerated expansion of renewable electricity generation, requirements for new fossil-fueled and nuclear power generation capacity are reduced. No new nuclear capacity is assumed to come on line after 2002. Some 8,000 MW of coal-fired power, 4,200 MW of gas-fired steam-cycle power plants, 17,000 MW of gas-fired combined-cycle plants, and 14,000 MW of oil-fired combined-cycle plants are assumed to be built between 1995 and 2020, with virtually all of the steam-cycle facilities added before 2005. In addition, roughly 85 percent of oil- and coal-fired generating capacity existing as of 1995, and about 40 percent of existing gas-fired capacity, is assumed to be retired or "mothballed" (placed on inactive but operable status) by 2020[aaaa].

6.5.3. Measures to address energy supply risks in the Alternative path

The measures that might be undertaken to reduce the risks of energy supply disruptions in the Alternative path are described below. Many of the measures noted under the discussion for the BAU path, including diversifying types of fossil fuels used and diversifying sources of fossil and nuclear fuel supply, would also be pursued under the Alternative path.

- **Aggressively pursue energy efficiency improvements in all end-use sectors and in fuels transformation (including electricity generation)**: Efficiency improvements enhance supply

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[aaaa] It is possible that some refurbishing/repowering of gas- or oil-fueled plants will take the form of conversion to combined-cycle facilities, so overall net retirements may not be as great as indicated.

security by reducing the relative severity (amount of supply reduced relative to need) of any given amount of supply restriction. The quantitative assumptions for many such measures are described above.

- **Aggressively research, develop, and implement a wide range of different renewable energy technologies, including those that might use energy resources from abroad**: The implementation of renewable energy supplies as described above will require a R&D effort that is both intensive and broad-based, going down many different technological "roads" to find those that are most suitable. It is possible that much of this effort—and the risk involved in the effort—can be spread by a process of international cooperation somewhat akin to what is happening today in space science and high-energy physics.
- **Minimize waste of materials in industrial production**: Reducing the amount of primary materials needed to produce final goods allows stockpiles of primary materials to last longer, which in turn helps to shielding the economy from some of the impacts of disruptions in energy supply. Reduction in primary materials use also could provide enhanced flexibility in dealing with short-term supply disruptions, as the output (and thus energy use) in energy-intensive primary materials industries could be reduced to free up fuel supplies for other uses.

6.5.4. Measures to address economic risks in the Alternative path

In the Alternative path, many of the measures that we assume would be used to address the economic risks associated with higher prices for oil or other key fuels (due to supply constrictions) overlap with or are complementary to measures to reduce the risks associated with supply disruption.

- **Reduce dependence on energy in general as a factor input**: This set of measures includes adopting production methods that use local materials, as well as those where labor can substitute (to some degree) for energy.
- **Increase use of domestic resources**
- **Encourage development of shared regional energy infrastructure and economic interdependence**: If protocols are set in place for regional cooperation in the event of, for example, an oil price hike, it is likely that the burden of such a hike can be shared among countries, thus reducing the impact of price increases on any one country[bbbb], and increasing the leverage of consumer nations in combating a price increase. The Alternative path, which includes broadened cooperation in, for example, gas pipelines, oil exploration, renewable technology development, and (starting in 2010 to 2020) trade in fuels derived from renewable resources, shows many examples of shared energy infrastructure and tightened regional economic interdependence.
- **Maintain stockpiles of key fuels at current (1995) volumes**
- **Encourage participation in energy markets by private sector actors to diversify risk**: In the Alternative path, we assume that relatively more and different actors will be involved in fuel and energy infrastructure financing, procurement, and operation than in the BAU path. Examples might include private (even foreign) financing and/or ownership of new types of electricity generation

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[bbbb] One could argue that, at present, Japan is probably able to out-bid other countries in the region in the event of fuel scarcity, thus regional coordination of fuel consumers in the region may in fact benefit other countries in the region to a greater extent than Japan, at least in the early stages of any price hike **[REVIEWERS—WORTH SAYING?]**.

facilities. Broader participation in energy markets helps spread the risk of economic damage due to higher prices.

6.5.5. Measures to address technological risks in the Alternative path

The measures that we assume will be incorporated into the Alternative path to (in part) address the risks of failure or rejection of particular technological initiatives include:

- **Diversify to increase the number of fundamentally different technologies being adopted, and encourage different R&D approaches to each technology**: As noted above, diversification may be aided by international cooperation on technology development.
- **Reduce the scale and increase the physical dispersal of key energy infrastructure**: Building power plants, for example, in smaller sizes, and siting them closer to load (or having load centers host small power plants) will both reduce the risks of losing a large amount of capacity due to any one event (accident or natural disaster, for instance), and may help to more evenly distribute the social burdens of energy infrastructure (see below).
- **Adopt technologies that can be developed and implemented quickly and flexibly**: Technologies that have can be developed more quickly can more flexibly adapt to changing physical, economic, social, or political conditions, and in addition may tend to have less associated bureaucratic "momentum" if the technology should prove to have a fatal flaw.

6.5.6. Measures to address environmental risks in the Alternative path

In the Alternative path, we assume that policies are instituted that spur a generally more proactive approach to environmental protection, relative to the BAU case. We assume that the Alternative path will include the following measures, many of which overlap with measures to address other risks:

- **Accelerate introduction of energy technologies that are less polluting in the first place**: Included in this category of technologies are, of course, those that consume less fuel, or do not use fossil fuels.
- **Reduce the scale of energy facilities**: Reducing the scale of energy facilities, in addition to augmenting flexibility in the face of changing conditions, may help to make the environmental impacts of each individual facility more manageable in scale.
- **Reduce flows of potentially environmentally-damaging materials through sensitive areas**: Improve the planning of transport of hazardous chemicals, wastes, and nuclear materials—and the siting of the facilities that generate or process them—so that transit of sensitive ecological (or cultural) areas is minimized. One specific measures of this type that we assume will be included in the Alternative path is that nuclear fuel reprocessing contracts between Japan and reprocessing centers in Europe are assumed to not be renewed when they lapse. Spent nuclear fuel, after cooling in pools at the reactor site, is assumed placed into "dry cask storage" and left on the reactor site or at a nearby interim storage facility[19].
- **Adopt industrial production methods (and goods consumption patterns) that minimize wastes and pollution**: As an example, the "hypercars" described above require far less steel and

other materials. Products in general can be designed so as to maximize the degree to which the materials of which the products are made can be recycled when the goods reach the end of their useful lives. This "recyclability by design" has the potential to further reduce the environmental impacts of primary materials production, processing, and waste disposal, as well as the energy use (and its environmental impacts) attendant at each step of the process.

- **Spur international cooperation to reduce GHG emissions, lead by example, and assist other countries in meeting GHG reduction goals**: Its expertise with technology and financial strength places Japan is in a unique position in Northeast Asia as both a "role model", leader, and source of wherewithal to help the region steer toward development with lower GHG emissions.
- **Develop plans for responding to impacts of climate change and other heightened environmental risks**: These plans should be developed in conjunction with other countries in the region.

6.5.7. Measures to address socio-cultural risks in the Alternative path

In the Alternative scenario, our assumption is that socio-cultural risks will be addressed by a variety of policies—again overlapping with those used to address other risks—that in general try to enhance the degree to which affected parties are included in energy-sector decision-making. At the same time, addressing socio-cultural risks under the Alternative path means attempting to minimize the environmental, aesthetic, or cultural impacts that increase risks. Particular measures to address socio-cultural risks might include:

- **Increase transparency in energy planning**: When the process of energy sector planning becomes more visible and easily understandable, it is more likely that the outcomes of the process will be accepted as general consensus, rather than as the output of an isolated group. Making the energy planning process more transparent will include assuring the involvement of stakeholder groups on the national, regional, local levels, and development of a consistent protocol for compensating local communities when local costs outweigh general benefits.
- **Reduce the scale, visibility, environmental impacts of energy facilities**
- **Adopt marketing approaches that allow consumers to "vote" on infrastructure**: "Green pricing", a electric utility billing system that is starting to be adopted in the United States, allows consumers to choose, for example, to pay a slightly higher price for electricity that is generated using more renewable resources.
- **Increase education on energy and environmental matters**: Here we mean both increasing the breadth of understanding of those who make energy-sector decisions, as well as providing sufficient general education that consumers are able to make informed and intelligent choices regarding the energy and environmental implications of their consumption patterns[cccc].

[cccc] See, for example, Wilkening, K., D. Von Hippel, and P. Hayes (1998), Sustainable Energy in a Developing World: The Role of Knowledgeable Markets. Prepared for the United Nations University Symposium on Environment (Group on Market Forces and Environment), November 14 - 15, 1997.

6.5.8. Measures to address military-security risks in the Alternative path

In the Alternative path, as in the BAU path, we would assume that Japan would pursue military cooperation agreements with the countries of the region. In addition, we would expect that there would be a greater effort under the Alternative path than under the BAU path to:

- **Seek regional cooperation on energy and environmental issues**: Goals of this type of regional cooperation—which might include monitoring and policing of shared sea lanes, and coordinating monitoring and clean-up of shared marine and atmospheric resources—include building of confidence between nations, lowered competition for resources, and more cooperative agreements for resource and technology sharing or trade.
- **Adopt technologies that minimize the transport of nuclear materials** (see section on measures to address environmental risks, above).

6.6. Testing the Performance of the BAU and Alternative Paths Under Major Perturbations

Our candidate paths have been designed, as described above, to address a host of different types of risk inherent in the operation and evolution of the Japanese energy economy. In order to test, in part, how well these risk management and risk mitigation strategies function for each of the two paths, we have devised a pair of very simple (and no doubt, to some degree, simplistic), entirely hypothetical "perturbations" of a "catastrophic" nature—events that have the potential to quickly cause a major change in the way that the Japanese energy system operates. The analytical goal is to compare the relative impacts of the perturbations on the two candidate energy paths. In particular, these variants of the two basic paths (path + perturbation) are used to test the relative efficacy, robustness, and flexibility of each path under a particular manifestation of risk and uncertainty.

We propose two different perturbations:

- An **oil price shock** caused by a major conflict in the Middle East
- An **accident** at a Japanese boiling water reactor (BWR)-type power plant precipitates the immediate and indefinite closure of all Japanese BWRs
- A major **environmental calamity**, such as the rapid collapse into the sea of a major portion of the West Antarctic Ice Sheet.

In each case, we propose that the perturbation takes place in the year 2010. This timing provides adequate time from the present for the energy systems under the BAU and Alternative cases to diverge significantly, while still providing ten years (before the end of our quantitative analysis in 2020) to test the impacts of the perturbations. Each of these hypothetical "catastrophes" is described briefly below. Our suppositions and analysis of how the Japanese energy system would respond differently, in the BAU and Alternative paths, to each of these challenges is described in Chapter 7.

OIL PRICE SHOCK

Judging that the international will to resolve conflicts is at a low ebb, an opportunistic and well-armed oil-producing Middle Eastern nation near the Persian Gulf invades its neighbor, also a major oil producer, in 2010. Oil production from both nations goes off-line immediately. The international response to the conflict is muddled and slow in coming, a lengthy stalemate is caused by the taking of hostages from the diplomatic community, and in the meantime all shipping out of the Gulf ceases, as the aggressor nation announces that it has placed mines in the major shipping channels. The net effect of these actions is to cause oil prices and oil price futures to rise almost immediately to $35 per barrel (in 1995 dollars), and to remain high levels through 2020, when additional capacity in non-Gulf states and/or an end to the conflict (with reconstruction of capacity in the combatant nations) increases the supply of oil again.

A NUCLEAR ACCIDENT

In 2010, a nuclear accident occurs such that containment is breached in one of the newer BWR plants in Japan. The accident could be the result of a seismic event. Although little radiation actually leaves the plant area, protracted social outcry about the accident, coupled with mis-handling of the accident by the plant operators, forces Japanese policy-makers to order all BWR units shut down until the debate as to the safety of the BWR design is resolved to the public's satisfaction. The process of resolving this debate takes until nearly 2020.

AN ENVIRONMENTAL CALAMITY

If a major portion of the Antarctic Ice Sheet were, as is apparently possible, to collapse and slide into the ocean, a major and rapid change in sea level would result. We have yet to "flesh out" this perturbation, but intend to do so with reference to some of the more catastrophic global warming scenarios evaluated by the IPCC. We have not yet had the opportunity to evaluate the potential consequences (quantitative or qualitative) of such an occurrence to Japan's energy system, but suspect that inundation of oil and LNG terminals, disruption of the shipping of all sorts, the flooding of the waterfronts of major cities, and many other impacts would be likely. Here the difference between different energy paths will be the degree to which a portion of the energy infrastructure can remain "on-stream" to help to start to rebuild in the wake of the disaster.

7. Results of Analysis

7.1. Introduction

The overall purpose of the first phase of the PARES project, in addition to developing a more inclusive definition for "Energy Security", has been to develop and apply a framework for the analysis of the Energy Security costs and benefits of different ways of supplying energy services. A framework for analysis is proposed in Chapter 5 of this document, and Chapter 6 sketches two of many different possible alternative "Energy Paths" that Japan might pursue between 1995 and 2020. In this Chapter, we apply the analytical framework drafted in Chapter 5 to the paths laid out in Chapter 6, and discuss the analytical results of a comparison of the two paths.

In this discussion of the relative energy security costs and benefits of the two energy paths, we outline the changes in overall fuel demand and supply situation that occur between 1995 and 2020 in the two paths, then evaluate the relative characteristics and impacts of the two paths with regards to the set of energy security dimensions identified in Table 5-1, namely:

- Energy Supply (total primary energy, imports, diversification by fuel type and supplier, stocks)
- Economic (total energy system costs, fuel costs, fuel import costs, economic impact of fuel price increase)
- Technological (diversification among technologies, diversification in R&D spending, reliance on proven technologies, technological adaptability)
- Environmental (emissions of greenhouse gases, acid gases, and local air pollutants, other air and water pollution, solid wastes, nuclear wastes, ecosystem and aesthetic impacts, and exposure to environmental risk)
- Social and Cultural (exposure to social and cultural risks)
- Military/Security (exposure to military and security risks, spending on energy-related security arrangements)

Following the discussion of results outlined above, we:

- Provide an overall matrix of results by energy security dimension and by path;
- Discuss the potential impact of path variants on the overall results;
- Suggest the implications of our results on the choice of energy paths for Japan and for other countries in the region; and
- Suggest some longer-term geopolitical/geoeconomic/geoenvironmental "scenarios" sketched out as part of the first PARES project meeting, and discuss how the medium-term energy "paths" that we have evaluated might (or might not) fit with those scenarios.

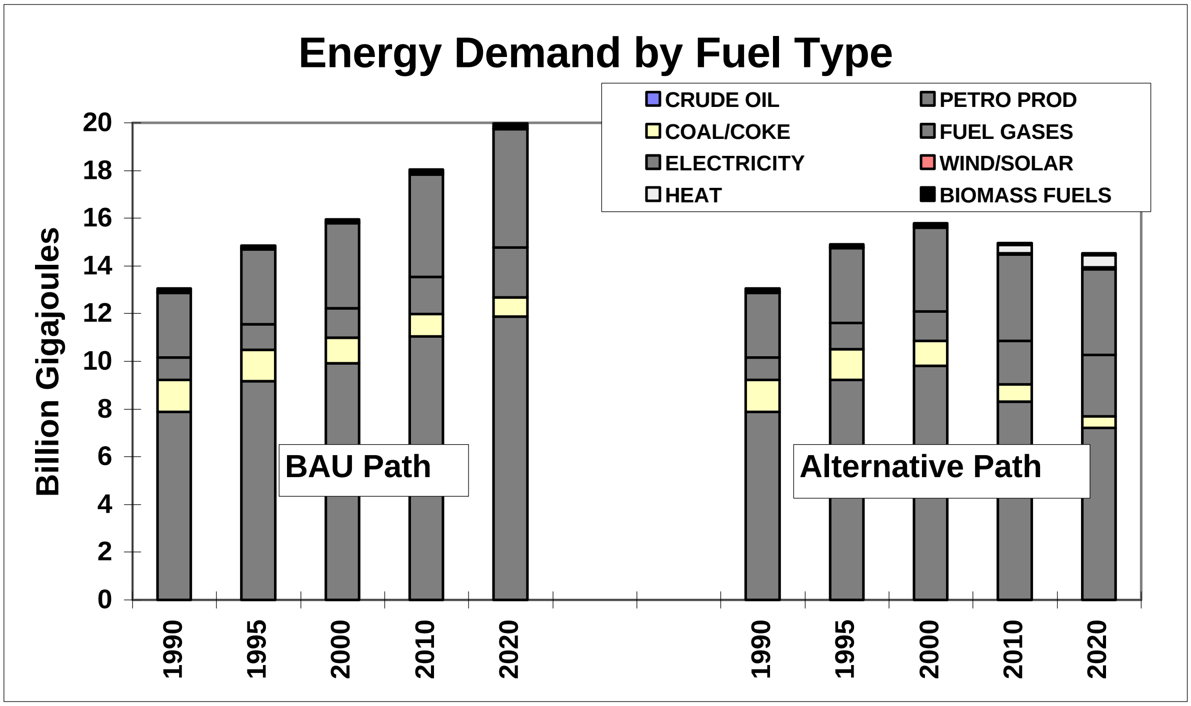
7.2. Energy Demand and Supply Under the BAU and Alternative Paths

The BAU and Alternative paths are designed to highlight different strategies for meeting Japan's needs for energy services over the period from 1995 to 2020. As such, it is not surprising that the future patterns of fuel demand and supply under the two paths are considerably different. The BAU path, for example, shows steady growth in overall fuel use, while energy use in the Alternative path actually declines after the year 2000. A selection of additional tables of demand and supply results for the two paths are provided in Attachment Set D to this Report.

7.2.1. Energy demand and supply: overall results

Figure 7-1 shows energy demand by fuel type (combining the several dozen fuel-types modeled into a smaller number of "balance sheet categories"). Between 1995 and 2020, energy use in Japan in the BAU path grows at an average rate of 1.2 percent per year. In the Alternative path, on the other hand, overall energy use actually declines, as a result of energy efficiency and other "demand-side" measures, from 14.9 billion gigajoules (GJ) in 1995 to 14.5 billion GJ in 2020, an average rate of decline of about 0.1 percent per year. Key differences between the paths in the relative fractions of fuel use include a much greater use of cogenerated heat and fuel gases in the Alternative path, as well as significantly less petroleum products (50 percent of demand versus 60 percent in the BAU path). The fraction of final fuels demand provided by electricity is about the same in both paths in 2010 and 2020.

Figure 7-1:



The change in energy demand by sector in the two different paths is shown in Figure 7-2. Here the most obvious difference between the two paths is the relative shares of total energy demand accounted for by the transport sector by 2010 and 2020. In 2010, the BAU-path share of total energy accounted for by the transport sector is 28.2 percent, falling slightly to 27.8 percent by 2020. In the

Alternative path, the transport-sector fraction of total energy demand is 22.4 percent in 2010, falling to less than 20 percent by 2020. This change in the relative importance of the transport sector between the two paths is due primarily to the assumptions about the use of high-efficiency road vehicles in the Alternative path.

Figure 7-2:

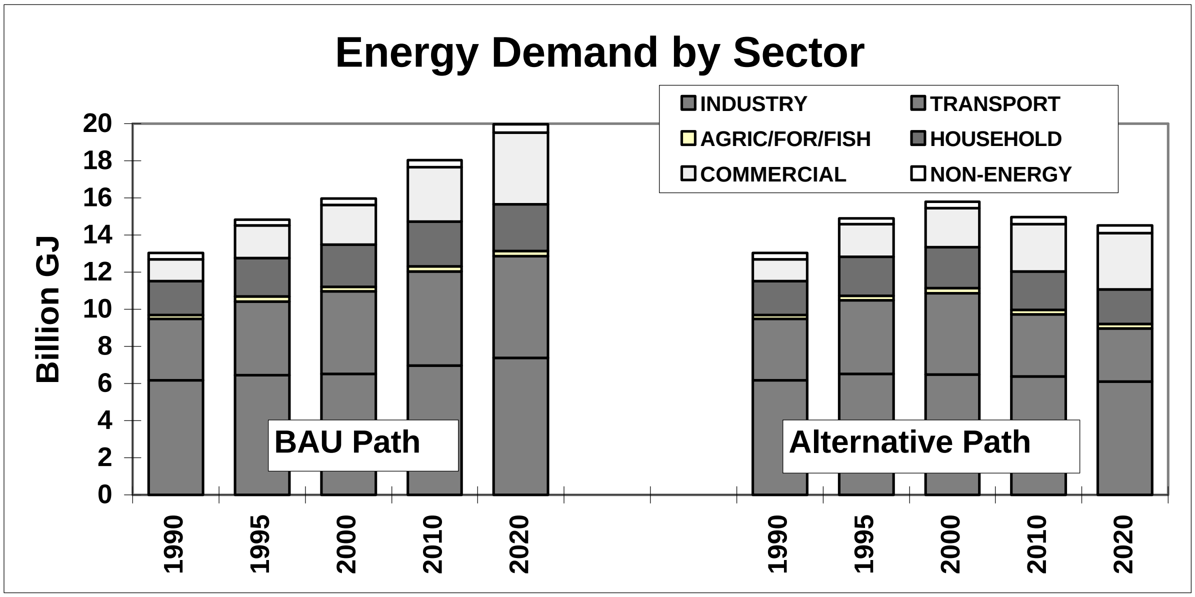


Table 7-1 summarizes the growth rates of energy demand, by sector, for the two paths. In both cases, the commercial sector (including services and public institutions) shows the strongest growth in energy consumption (as per recent trends in Japan). For all other major sectors, overall energy use grows slowly in the BAU path, but declines in the Alternative path.

Table 7-1:

Growth of Overall Sectoral Energy Demand 1995 to 2020 (Average Annual Growth)

SECTOR	BAU Path	Alternative Path
INDUSTRY	0.5%	-0.2%
TRANSPORT	1.3%	-1.3%
AGRIC/FOR/FISH	0.2%	0.0%
HOUSEHOLD	0.8%	-0.5%
COMMERCIAL	3.2%	2.2%
NON-ENERGY	1.2%	1.2%
TOTAL	**1.2%**	**-0.1%**

Turning to the overall fuel resource use implied by the two energy paths for Japan, Table 7-2 presents the total primary fuel supplies used in 1995 and, under the two different paths, in 2010 and 2020. The primary differences between the paths are:

- Overall primary fuel use in 2020 is nearly 25 percent lower in the Alternative path than in the BAU path, and, in fact, is only modestly higher than in 1995.

- The use of biomass fuels and, especially, wind and solar energy is much higher in the Alternative path than in the BAU path.
- Under the Alternative path, Japan becomes a net exporter of petroleum products by 2010, with exports of (principally) gasoline and heavy oil more than offsetting imports of LPG and Naptha. (Exports are reflected by the negative values for petroleum products in Table 7-2.)
- Crude oil imports to Japan under the Alternative path are about 15 percent less, by 2020, than in the BAU path.
- By 2020, about half as much coal is used in the Alternative path as in the BAU path.
- The amount of nuclear fuel used in the Alternative path in 2020 is approximately 17 percent less than the nuclear fuel used in the BAU path, but because less primary fuel is used overall, nuclear fuel constitutes a slightly greater share of the 2020 energy mix (10.6 versus 11.2 percent) in the Alternative path.
- Fuel gases—mostly natural gas/LNG—constitute a larger share of the energy mix by 2020 in the Alternative path than in the BAU path. The absolute amount of fuel gases used in the Alternative path, however, is slightly lower, as a result of (mostly) energy efficiency measures and cogeneration, than in the BAU path.
- Fossil fuel use in the BAU path in 2020 is about 24.9 billion GJ, versus 16.3 billion GJ (about 65 percent of the BAU level) in the Alternative path.

Table 7-2:

PRIMARY SUPPLIES OF FUELS AND RESOURCES
BY BALANCE CATEGORY (BILLION GIGAJOULES)

		BAU Path		**Alternative Path**	
FUEL/RESOURCE	1995	2010	2020	2010	2020
CRUDE OIL	10.98	11.29	11.33	10.89	9.66
PETRO PROD	0.69	3.2	4.54	-0.16	-0.28
COAL/COKE	3.41	3.42	3.78	2.43	1.95
FUEL GASES	2.23	3.66	5.22	3.94	4.98
HYDRO/GEOTHERM	0.44	0.44	0.44	0.44	0.44
WIND/SOLAR	0.04	0.05	0.05	0.6	2.16
NUCLEAR	3.18	3.88	3.06	3.55	2.53
BIOMASS FUELS	0.28	0.29	0.29	0.35	0.39
TOTAL	21.25	26.23	28.71	22.04	21.83

FRACTION OF TOTAL PRIMARY FUEL SUPPLY

		BAU Path		Alternative Path	
FUEL/RESOURCE	1995	2010	2020	2010	2020
CRUDE OIL	51.7%	43.0%	39.5%	49.4%	44.3%
PETRO PROD	3.2%	12.2%	15.8%	-0.7%	-1.3%
COAL/COKE	16.0%	13.0%	13.2%	11.0%	8.9%
FUEL GASES	10.5%	14.0%	18.2%	17.9%	22.8%
HYDRO/GEOTHERM	2.1%	1.7%	1.5%	2.0%	2.0%
WIND/SOLAR	0.2%	0.2%	0.2%	2.7%	9.9%
NUCLEAR	15.0%	14.8%	10.7%	16.1%	11.6%
BIOMASS FUELS	1.3%	1.1%	1.0%	1.6%	1.8%
TOTAL	100%	100%	100%	100%	100%

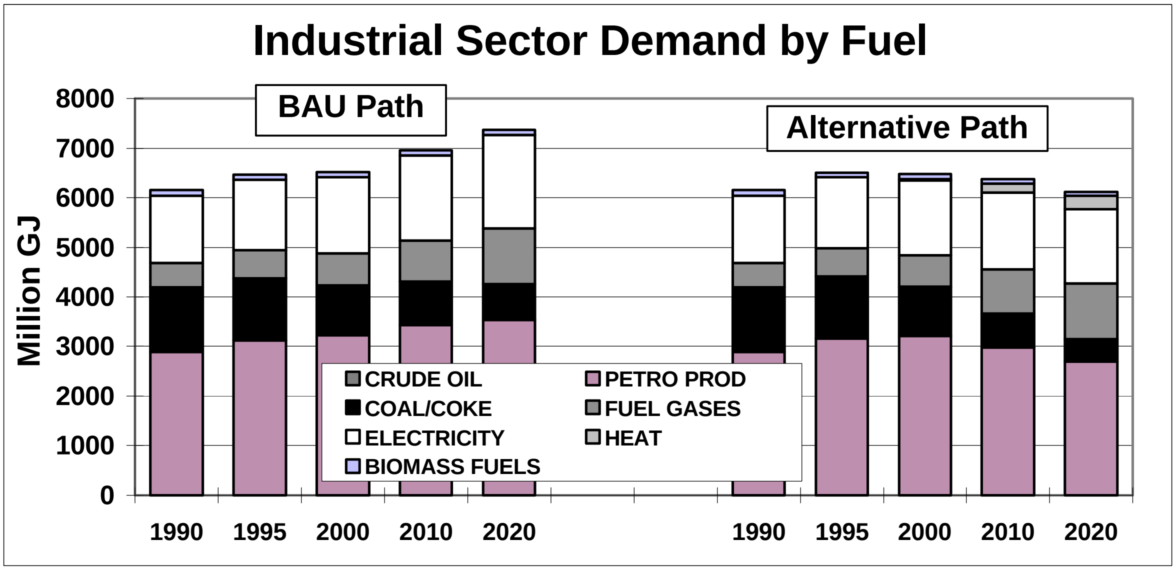
Fuel and resource imports under the two paths show similar patterns to overall primary energy use. Overall fuel imports in the Alternative scenario by 2020 are about 75 percent of those in the BAU scenario, with petroleum products and coal imports in the Alternative path approximately half of those in the BAU path.

7.2.2. Key results by sector, fuel, and transformation process

Figure 7-3 shows the industrial sector demand by fuel type for the two paths. Key differences between the paths are:

- In the Alternative path, industrial dependence (the fraction of total fuel demand provided by each fuel) on fuel gases and cogenerated heat increases markedly between 1995 and 2020, dependence on electricity increases somewhat, the fraction of industrial energy demand provided by petroleum products decreases somewhat, and the use of coal and coke declines significantly.
- In the BAU path, use of electricity as a fraction of total demand increases somewhat more than in the Alternative path, coal use declines, but not as steeply, petroleum products use as a fraction of total demand remains relatively stable from 1995 to 2020, and the proportional use of fuel gases increase, but not as rapidly as in the Alternative path.

Figure 7-3:



In the transport sector, the major differences between the two paths are the very significant decrease in the use of petroleum products in the Alternative path (2020 demand for petroleum fuels in the Alternative path is approximately half that in the BAU path), and the growing fraction of transport fuels provided by fuel gases (CNG and hydrogen) in the Alternative path. Both paths use about the same amount of electricity for transport.

Household use of petroleum products and electricity is significantly lower, by 2010 and 2020, in the Alternative path than in the BAU path, while use of fuel gases is about a third higher (by 2020) in the Alternative path.

In the Commercial/Services/Public sector, as indicated in Table 7-3, year-2020 use of petroleum products and coal/coke are nearly 50 and 40 percent lower, respectively, in the Alternative path than in the BAU path, and use of electricity is 29 percent lower. Conversely, sectoral use of fuel gases is nearly 50 percent higher in the Alternative path, by 2020, than in the BAU path.

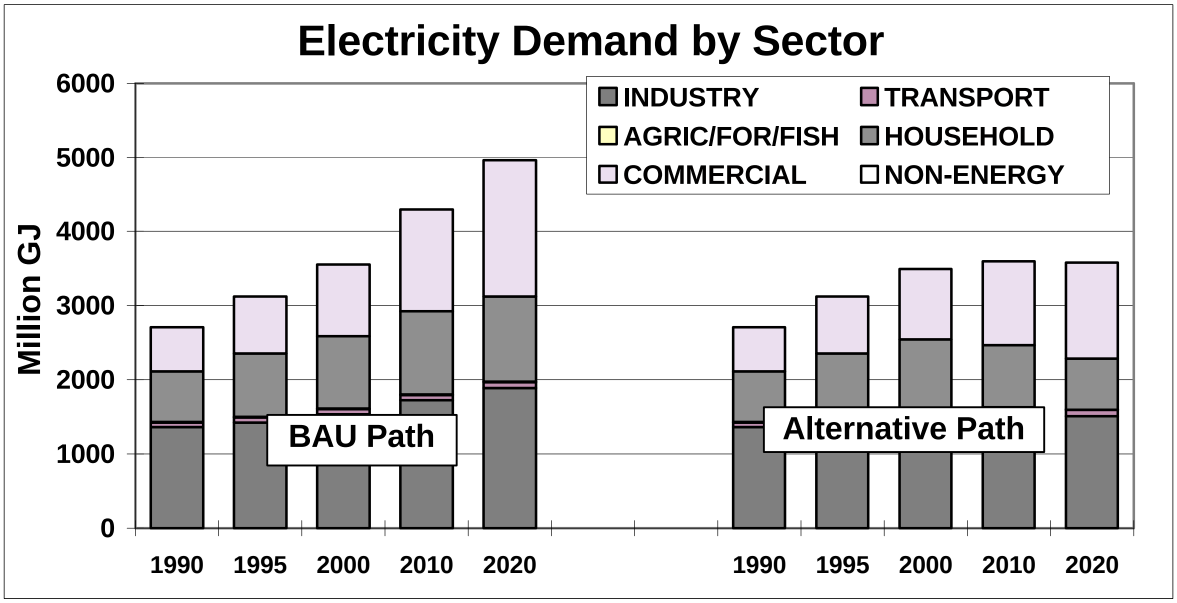
Table 7-3:

FUELS DEMAND IN THE COMMERCIAL/SERVICES SECTOR UNDER TWO ENERGY PATHS (MILLION GIGAJOULES)

		BAU Path		**Alternative Path**		**Alternative/BAU**	
FUEL	1995	2010	2020	2010	2020	2010	2020
PETRO PROD	744	1,114	1,393	807	706	72%	51%
COAL/COKE	43	61	75	45	46	73%	61%
FUEL GASES	179	349	494	380	728	109%	148%
ELECTRICITY	766	1,376	1,833	1,137	1,297	83%	71%
HEAT	14	48	83	168	246	348%	297%
TOTAL	1,747	2,949	3,878	2,536	3,024	86%	78%

Examining the sectoral structure of demand results by major fuel type, Figure 7-4 shows the difference in electricity demand by sector between the two paths. In the BAU path, electricity demand grows at an average rate of 1.9 percent annually from 1995 to 2020. In the Alternative path, electricity use grows at only 0.6 percent annually over the same period, and actually declines somewhat between 2010 and 2020. By sector, the commercial/services sector constitutes the major source of growth in electricity consumption in both paths. Although electricity use in the industrial sector continues to grow (at an average of 1.1 percent/yr in the BAU path, and at 0.2 percent per year in the Alternative path), the fraction of electricity used by industry declines in both paths. Household electricity demand shows the greatest difference in growth in the two scenarios, increasing at an average rate of 1.2 percent/yr (1995 to 2020) in the BAU path, but falling at an average rate of 0.9 percent per year in the Alternative path.

Figure 7-4:



Year-2020 shares of petroleum fuel demand by sector are substantially different in the BAU and Alternative paths. In the Alternative path, the industrial and transport sectors each account for about the same share (about 37 percent) of total petroleum products demand. In the BAU case, the transport sector accounts for more than 45 percent of demand.

Overall final demand for fuel gases is higher in the Alternative path than in the BAU path by 2020 (by about 23 percent) but absolute industrial sector demand for fuel gases is similar in the two paths. Household and commercial-sector demand for fuel gases is higher in the Alternative path than in the BAU path.

Electricity generation and overall generation capacity in the Alternative path is less than in the BAU path, and different technologies are used to generate electricity. A summary of electricity generation by major fuel/technology type is provided in Table 7-4. Key results here include much broader use of wind and solar power generation in the Alternative path, and a focus on newer generating facilities, notably combined-cycle facilities. Total power generation remains roughly constant from 2000 on in the Alternative, path; whereas in the BAU path generation rises by an average of 1.5 percent per year between 2000 and 2020. The share of generated power provided by nuclear power is slightly higher in the Alternative path in 2010 and 2020 than in the BAU path, although the total nuclear generation in the Alternative path is substantially less. This somewhat counter-intuitive result stems, in large part, from using the same phase-out schedule for Japan’s existing nuclear capacity in both paths, while existing fossil-fueled facilities are phased out more rapidly in the Alternative path. Overall, fossil-fueled generation in 2020 falls from 76 percent of all generation (excluding pumped-storage hydro) in the BAU path to 60 percent in the Alternative path.

Table 7-5 presents a similar picture of changes in generating capacity under the two paths. Here the share of nuclear capacity in the two paths is quite similar, although the total nuclear capacity by 2020 in the Alternative path is some 7 GW less than in the BAU path. In the BAU path, by 2020, about 70 percent of all generation is fossil- fueled, while in the Alternative path, only about 46 percent of total 2020 capacity is fueled with gas, oil, or coal.

In both paths, all generating facilities operate at or near their maximum capacity factors from the year 2000 on.

Table 7-4:

ELECTRICITY GENERATION: ENERGY OUTPUTS BY PLANT TYPE FOR TWO ENERGY PATHS (THOUSAND GIGAWATT-HOURS)

		BAU Path			Alternative Path		
PLANT TYPE	1995	2000	2010	2020	2000	2010	2020
Nuclear	292	319	356	280	324	326	232
Conventional Hydro	101	101	101	101	101	101	101
Pumped-Storage Hydro	20	20	23	25	20	23	25
Geothermal	2	2	2	2	2	2	2
Gas-fired, Existing	181	181	181	181	181	154	105
Coal-fired, Existing	172	172	172	172	172	118	79
Oil-fired, Existing	219	272	293	303	255	179	66
Gas-fired, New	-	26	110	232	23	67	136
Coal-fired, New	-	16	63	134	8	30	53
Oil-fired, New	-	6	35	89	6	30	90
Gas-Cogen, New	-	-	-	-	5	54	92
MSW and Biomass	12	12	12	12	12	25	34
Wind Power	-	-	-	-	0	14	58
Solar	-	-	-	-	0	10	39
TOTAL	**999**	**1,128**	**1,349**	**1,533**	**1,110**	**1,133**	**1,110**

FRACTION OF GENERATION BY PLANT TYPE

		BAU Path			Alternative Path		
PLANT TYPE	1995	2000	2010	2020	2000	2010	2020
Nuclear	29%	28%	26%	18%	29%	29%	21%
Conventional Hydro	10%	9%	8%	7%	9%	9%	9%
Pumped-Storage Hydro	2%	2%	2%	2%	2%	2%	2%
Geothermal	0%	0%	0%	0%	0%	0%	0%
Gas-fired, Existing	18%	16%	13%	12%	16%	14%	9%
Coal-fired, Existing	17%	15%	13%	11%	16%	10%	7%
Oil-fired, Existing	22%	24%	22%	20%	23%	16%	6%
Gas-fired, New	0%	2%	8%	15%	2%	6%	12%
Coal-fired, New	0%	1%	5%	9%	1%	3%	5%
Oil-fired, New	0%	1%	3%	6%	1%	3%	8%
Gas-Cogen, New	0%	0%	0%	0%	0%	5%	8%
MSW and Biomass	1%	1%	1%	1%	1%	2%	3%
Wind Power	0%	0%	0%	0%	0%	1%	5%
Solar	0%	0%	0%	0%	0%	1%	4%
TOTAL	100%	100%	100%	100%	100%	100%	100%

Table 7-5:

ELECTRICITY GENERATION: GENERATING CAPACITY BY PLANT TYPE FOR TWO ENERGY PATHS (THOUSAND MEGAWATTS)

		BAU Path			**Alternative Path**		
PLANT TYPE	1995	2000	2010	2020	2000	2010	2020
Nuclear	42	46	51	40	46	46	33
Conventional Hydro	21	21	21	21	21	21	21
Pumped-Storage Hydro	22	22	26	28	22	26	28
Geothermal	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Gas-fired, Existing	41	41	41	41	41	35	24
Coal-fired, Existing	26	26	26	26	26	18	12
Oil-fired, Existing	66	66	66	66	62	37	13
Gas-fired, New	-	5.4	21	42	5	11	21
Coal-fired, New	-	2.4	10	20	1.2	4.5	8
Oil-fired, New	-	1.2	7	16	1.2	5.0	14
Gas-Cogen, New	-	-	-	-	1.1	13	22
MSW and Biomass	2.0	2.0	2.0	2.0	2.0	4.0	5.5
Wind Power	-	-	-	-	0.0	5.5	22
Solar	-	-	-	-	0.1	6.9	25
TOTAL	**220**	**233**	**270**	**303**	**230**	**234**	**249**

FRACTION OF GENERATING CAPACITY BY PLANT TYPE

		BAU Path			**Alternative Path**		
PLANT TYPE	1995	2000	2010	2020	2000	2010	2020
Nuclear	19%	20%	19%	13%	20%	20%	13%
Conventional Hydro	10%	9%	8%	7%	9%	9%	8%
Pumped-Storage Hydro	10%	10%	10%	9%	10%	11%	11%
Geothermal	0%	0%	0%	0%	0%	0%	0%
Gas-fired, Existing	19%	17%	15%	13%	18%	15%	9%
Coal-fired, Existing	12%	11%	10%	9%	11%	8%	5%
Oil-fired, Existing	30%	28%	24%	22%	27%	16%	5%
Gas-fired, New	0%	2%	8%	14%	2%	5%	9%
Coal-fired, New	0%	1%	4%	7%	1%	2%	3%
Oil-fired, New	0%	1%	2%	5%	1%	2%	6%
Gas-Cogen, New	0%	0%	0%	0%	0%	6%	9%
MSW and Biomass	1%	1%	1%	1%	1%	2%	2%
Wind Power	0%	0%	0%	0%	0%	2%	9%
Solar	0%	0%	0%	0%	0%	3%	10%
TOTAL	100%	100%	100%	100%	100%	100%	100%

Key differences between the BAU and Alternative paths for other fuels transformation processes include:

- The use of pipeline gas to offset added LNG terminal capacity (although capacity factors for LNG terminals are generally around 50 percent for 1995 to 2020 under both paths;
- The export of more petroleum products (and reduction of petroleum products and crude oil imports) under the Alternative path (as noted earlier); and
- The beginning of hydrogen imports (or unspecified domestic production) after 2010 in the Alternative path.

7.3. Evaluation of Energy Security Impacts of Candidate Path Examples

The previous section of this Chapter provides an overview of the energy demand and supply situations resulting from the Business-as-Usual and Alternative paths that were sketched out in Chapter 6. In this section, we attempt to measure, quantitatively and qualitatively, the relative energy security impacts of each of the two illustrative paths. The measurements of energy security applied below are those we identified as "energy security dimensions" and attributes in Chapter 5 of this report. No one measure of energy security, as broadly defined, is likely to definitively lift a particular path to a place of prominence over other candidate paths. It is a premise of this report, however, that analysis of a range of analytical attributes of each of the candidate paths can help to indicate which paths provide more robust means of meeting energy security goals.

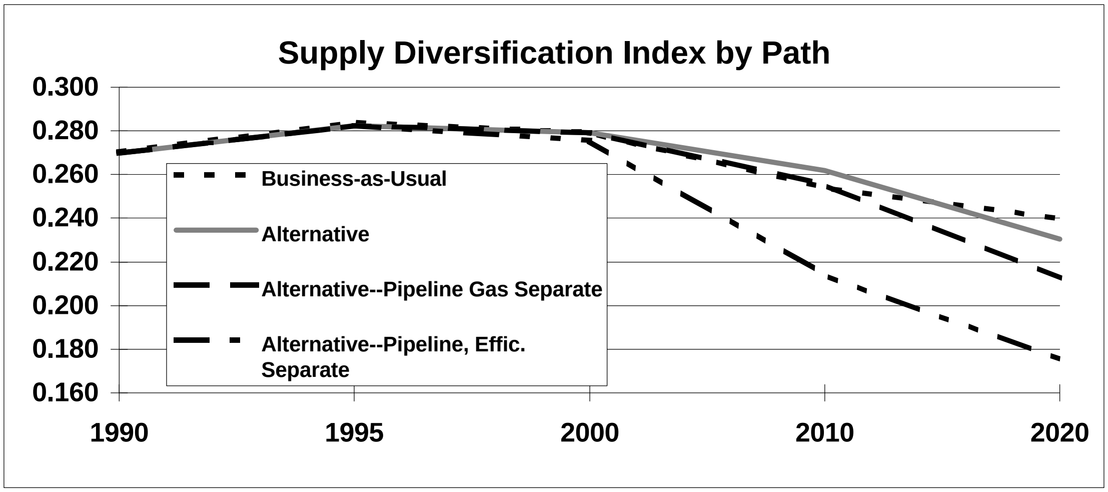
7.3.1. Energy Supply dimension

We use several energy supply attributes to compare the relative costs and benefits of the BAU and Alternative energy paths:

- **Total primary energy**—Although it cannot necessarily be said that higher total primary energy use is necessarily either better or worse in a given situation, it can certainly be argued that higher primary energy use is, all things being equal, at least an indirect indicator of less security in energy supply. In the BAU path, total primary energy use for Japan in 2010 is 26.2 billion GJ, versus 22.0 billion GJ in the Alternative path. By 2020 the disparity in primary energy use is greater: 28.7 billion GJ in the BAU path, and 21.8 billion GJ in the Alternative path.
- **Imports—**All else being equal, the fraction of total energy supply provided by imported sources would generally be considered more "secure" than the fraction of supplies that must be imported. In the BAU path, fuel imports net of exports in 2020 constitute over 96 percent of Japan's total primary fuel supply, whereas in the Alternative path, 85 percent of 2020 supply is from net imports.
- **Diversification of energy supply by fuel type—**Applying the diversification index concept (in its simplest form) as described by Dr. Neff in his paper in Attachment Set A (and summarized in Chapter 5 of this report), we derive the diversification indices presented in Figure 7-5 for the two paths over the period from 1990 to 2020. Note that there are a number of different ways of aggregating fuel types to calculate these indices. We have chosen, for convenience, to base the indices on the "balance categories" presented (for example) in Table 7-2, above, although other aggregations may be equally or more defensible. In both the BAU and Alternative paths, the diversification index declines (diversity of fuel supply increases) modestly from about 1995 on. The 2010 diversification index for the BAU path is actually slightly lower than that for the Alternative path, but by 2020 the index for the Alternative path falls below that of the BAU path, but not dramatically so. If one considers pipeline imports of gas and LNG gas imports to be sufficiently different as to provide fully independent fuel supplies (as is arguably the case), then the diversification index in the Alternative path is still lower, as is shown by the solid line in Figure 7-5. Another potential modification to the diversification index is to consider the difference in energy demand between the two paths to be mainly due to end-use energy efficiency measures, and to treat that difference, effectively, as a separate fuel or resource. If energy efficiency is considered as a fuel in this way, the diversification index for the Alternative path improves still further, falling to .175 by

2020[dddd]. Calculating a set of diversification indices based on imports alone yields a somewhat different result: the diversification index for the Alternative path remains near 0.29 to 0.30 from 1990 to 2020, while the index for the BAU path is lower in 2010 and 2020, falling to 0.27 and 0.255, respectively.

Figure 7-5:



- **Diversification by supplier**—The level of detail in our specification of the two energy paths presented here is insufficient to calculate values of the diversification index by nation supplying fuel to Japan. Qualitatively, however, one would expect that the efforts to encourage development of shared regional energy infrastructure and economic interdependence (see Section 6.5.4) to result in a more diverse set of fuel suppliers both across fuels and within specific fuel types (notably crude oil and fuel gases). This will be particularly true to the extent that Japan seeks trading partners and fuel supply investment opportunities outside the countries of OPEC, whose oil supply patterns (and prices) are (at least somewhat) more likely to be coordinated than those of non-OPEC nations.
- **Stocks as a fraction of supply**—Our working assumption for both the BAU and Alternative paths was that fuel stockpiles would be maintained at 1995 levels. Focusing for the moment on crude oil and petroleum products, the increase in demand in the BAU case means that a stockpile volume sufficient for 150 days of demand in 1995[20] would last for approximately 120 days in 2010 and 110 days in 2020. The same stockpile, under the Alternative path, would last 163 and 187 days in 2010 and 2020, respectively. A stockpile of nuclear fuel of a fixed extent would likewise go further—about 11 and 23 percent further in 2010 and 2020—in the Alternative path than in the BAU path. Coal stockpiles would also last considerably longer under the Alternative path, while the days of demand that could be met by similar-sized gas stocks in the two paths would not be much different.

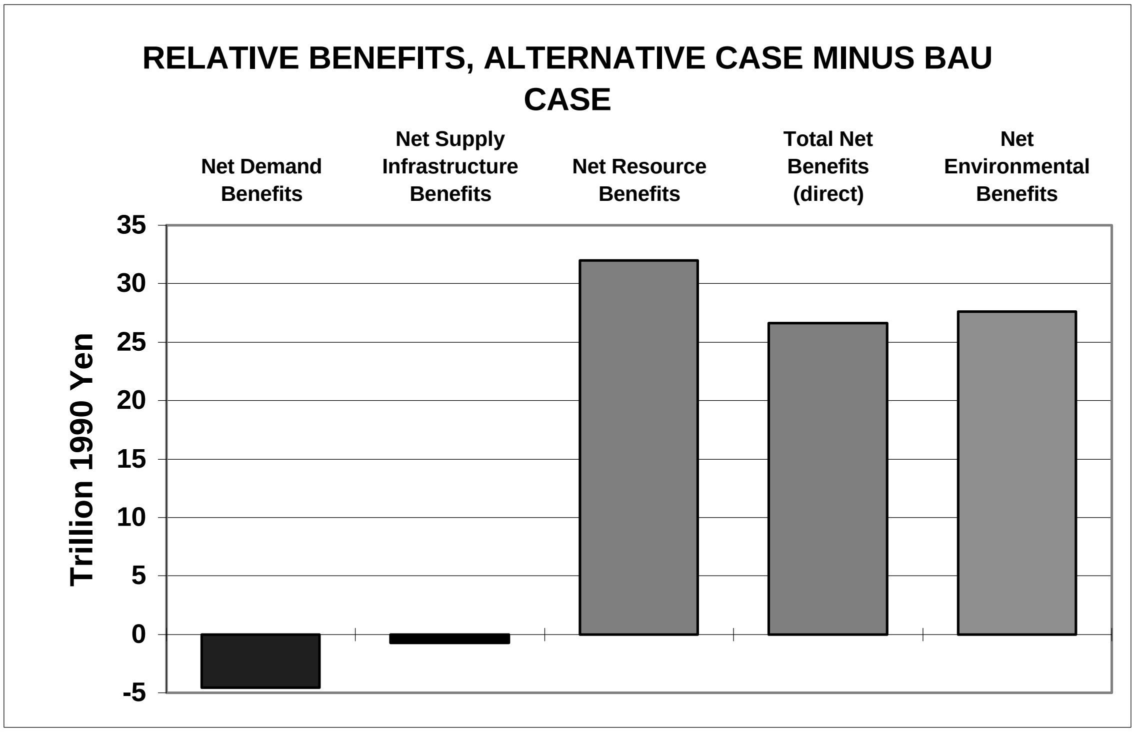
[dddd] This incorporation of energy-efficiency measures into the diversification index calculus is admittedly crudely done, as some energy efficiency measures are also applied in fuel transformation processes. Also, it is not entirely clear that energy efficiency should be treated as a single “fuel”, for the purposes of calculating diversification indices, as many different, arguably independent technologies are used to achieve energy savings. Of course, the same argument could be made for fuels from independent suppliers.

7.3.2. Economic dimension

Measures of the economic dimension of energy security include the direct costs of the energy system itself, and the relative impact of uncontrollable economic events when different energy paths are used. Our analysis of the economic dimension of energy security examined—in a relative sense—the following attributes of the BAU and alternative energy paths:

- **Total energy system costs**—Figure 7-6 provides a summary of the relative benefits, by major cost/benefit category, of moving from the Business-as-Usual path to the Alternative path. The total net present value (NPV) difference—using a real discount rate of 2 percent per year—in net benefits (including demand costs, supply infrastructure costs, and resource costs) between the two paths is about 27 trillion 1990 Yen. If one assumes an additional environmental benefit of (for example) 6750 Yen per tonne of carbon dioxide emissions avoided (about $50 per tonne of CO_2, or about $14 per tonne of carbon), an additional benefit of about 27 trillion Yen accrues in moving from the BAU to the Alternative path.

Figure 7-6:



- **Fuel Costs**—As indicated in Figure 7-6, fuel costs in the Alternative path, summed over 1990 to 2020, are nearly 32 Trillion Yen less than in the BAU path. The bulk of these costs are import costs[eeee].

[eeee] Note that neither the total cost or fuel cost comparison incorporate the BAU measure, described in section 6.4.4, calling for investment in commodity futures. The same fuel prices are thus used in evaluating both paths.

- **Economic impact of fuel price increase—**If, as a result of the Middle East conflict postulated in Section 6.6 of this report, crude oil prices rise in 2010 to the $35 per barrel (4,725 Yen per bbl) range, the relative benefits, in terms of resource costs of the Alternative scenario are even greater. Assuming that petroleum products prices track the increase in the price of crude oil, and that the prices of alternative fuels (notably LNG and coal, assuming that pipeline gas is more likely to be supplied on a long-term price contract) exhibit about half the rise in price, on a proportional basis, of the price of crude, the difference in resources costs between the two paths, on an NPV basis, rises to 54 trillion Yen. The impact of the rise in price is therefore about 27 trillion Yen higher in the BAU case than in the Alternative case. On an annual cost basis, for the year 2015 (as an example), the resource cost difference between the two paths is about 6.5 trillion Yen, which is on the order of 1 percent of our assumption as to Japan's overall GDP in 2015. This analysis of the relative impact of price increases is, quite admittedly, overly simplistic, as it ignores the potential price-stabilizing benefits of long-term oil price contracts, as well as the ameliorating effects of adjustment of the economy to higher oil prices. With regard to adjustment to higher oil prices, one might expect that the Alternative path, with its greater availability and diversity of energy-efficiency and alternative energy technologies, would allow a more rapid (and less economically painful) structural adjustment to higher prices than would the BAU path.

Our analysis of the economic costs and benefits of the BAU and Alternative energy paths for Japan is, quite admittedly, crude and incomplete. We have not explored, for example, the potential interaction between the technological changes in the Alternative path and the reduced requirements for industrial production of materials such as steel (for the auto industry). Some of the many areas where additional data and analysis might be used to improve this economic evaluation are indicated in Chapter 8 of this report. Still, the clear conclusion of our economic analysis to date appears to be that the net economic benefits of moving toward an energy path more like the Alternative path described here—both in terms of overall costs under routine conditions and security from energy price risks—are substantial.

7.3.3. Technological dimension

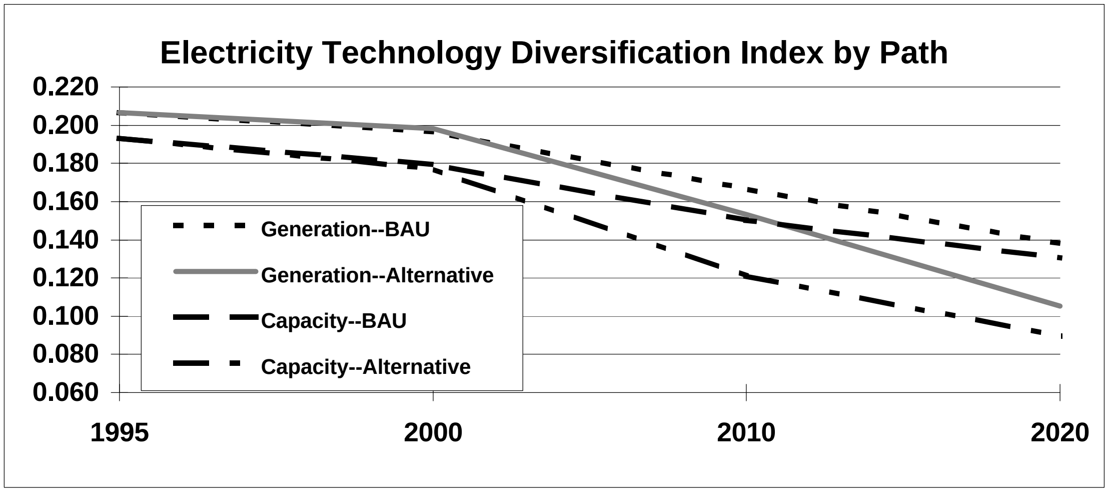
The technological dimension of energy security can be measured by criteria of technological diversity, diversification of technological effort, the degree to which the technologies to be used are already proven to work, and the adaptability of different technologies. The attributes of the BAU and Alternative paths with respect to each of these measures are discussed below.

- **Technological diversity—**In general, the Alternative path calls upon a wider array of technologies, both on the demand- and supply-sides of the energy balance, than the BAU path. Application of the diversification index described by Dr. Neff to, as an example, the electricity generating technologies used in the two paths yields the comparison shown in Figure 7-7. Here again, caution should be used in interpreting results that may be sensitive to the way in which electricity generation technology types are aggregated. Overall, however, the Alternative path yields somewhat more diversity in electricity generation and in electric generating capacity than does the BAU case.
- **Diversity of Research and Development spending—**We have made no specific projections of R&D spending by type of technology as part of the paths analyses. It is evident, however, that

achieving the energy-efficiency and renewable energy targets laid out in the Alternative path will requires a much greater diversity (and probably total amount) of R&D spending than would be required in the BAU path, where most of the technologies used are already well-proven (as noted below).

- **Reliance on proven technologies**—The Alternative path calls for extensive and rapid deployment of technologies not now in commercial (and, in some cases, not even in prototype) production. The BAU path, on the other hand, relies primarily on technologies now in use, or in relatively conservative variations of proven technologies. To the extent that reliance on untested technologies presents risks, the BAU path offers less technological risk.

Figure 7-7:



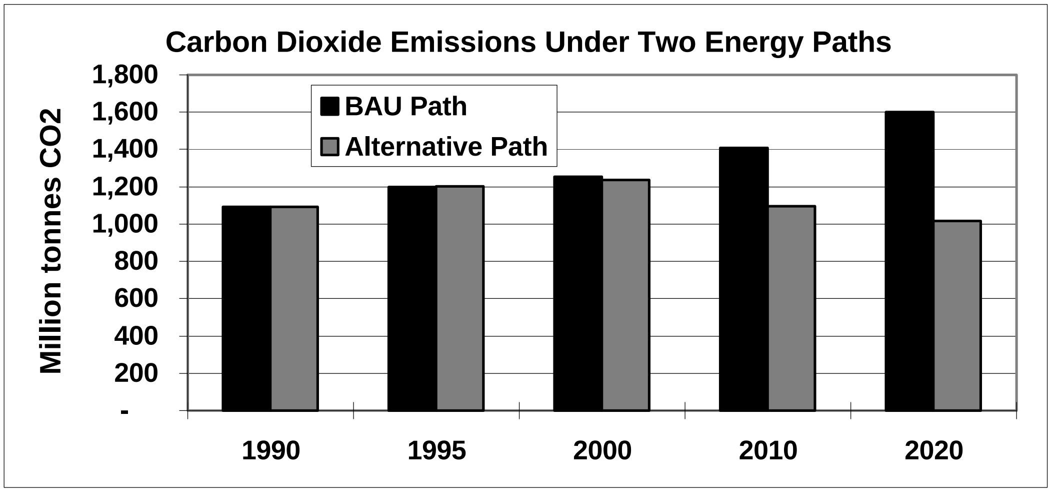
- **Technological adaptability**—As many of the technologies used in the Alternative path, including energy-efficiency technologies, cogeneration, and wind and solar power technologies, are available in smaller modules than the (for example) larger power plants that dominate the BAU path. More modular technologies can generally be deployed more rapidly, and in that sense are more adaptable. In addition, the higher level and diversity of technological R&D spending in the Alternative path suggests that the Japanese economy, under the Alternative path, will be better able to adapt to technological problems and opportunities that arise.

7.3.4. Environmental dimension

As indicated in Table 5-1, our attributes, or measures, for the environmental dimension of energy security include quantitative estimates of emissions of air and water pollutants, solid wastes, nuclear wastes, as well as more qualitative consideration of ecosystem and aesthetic impacts, and of exposure to environmental risk. The two candidate energy paths fare as follows with regard to these measures of the environmental dimension of energy security:

- **Greenhouse gas emissions—**Figure 7-8 compares the emissions of carbon dioxide[ffff] in the BAU and alternative paths. By 2010, emissions in the Alternative path are substantially lower than in the BAU path, and year 2020 emissions in the Alternative path are 63 percent of those in the BAU path. In the Alternative path, year 2010 emissions are about the same as 1990 emissions, and 2020 emissions are about 8 percent below 1990 levels. Emissions estimates for other greenhouse gases are more prone to uncertainty than estimates for CO2 emissions, but our rough figures indicate that nitrous oxide emissions under the Alternative path are about two-thirds of those in the BAU path by 2020, while 2020 methane emissions in the Alternative path are somewhat above BAU values, probably due to increased use of LNG and pipeline gas in the end-use sectors.

Figure 7-8:



- **Emissions of Acid Gases**—In our initial estimate—which should be refined with better emission factors for Japanese equipment and better estimates of average fuel composition in Japan—sulfur oxides emissions in the Alternative path are about 1.1 million tonnes, in 2020. Corresponding emissions of SO_x in the BAU case are slightly under 2 million tonnes. Nitrogen oxide emissions in 2020 in the BAU case are estimated at 5.2 million tonnes, versus 3.2 million tonnes in the BAU case.

- **Emissions of Local Air Pollutants**—In addition to sulfur and nitrogen oxides—which can be local as well as regional air pollutants, we estimated emissions of hydrocarbons, carbon monoxide, and particulates under the two paths. Emissions results for these pollutants are provided in Table 7-6. By the year 2020, emissions of these pollutants in the Alternative path are about 50 to 75 percent of emissions in the BAU path.

[ffff] The values in Figure 7-8 reflect only CO_2 emissions from fossil fuels, and thus exclude emissions from biomass fuels. Also, note that we list CO_2 emissions per tonne of molecular carbon dioxide. To convert these emissions figures to tonnes of carbon, multiply by 12 and divide by 44.

Table 7-6:

ESTIMATED EMISSIONS OF LOCAL AIR POLLUTANTS (Thousand Tonnes)					
		BAU Path		Alternative Path	
POLLUTANT	1995	2010	2020	2010	2020
CARBON MONOXIDE	2,840	3,484	3,791	3,106	2,794
HYDROCARBONS	842	993	1,054	640	549
PARTICULATES	910	933	939	706	537

- **Emissions of Other Air and Water Pollutants**—We have not attempted to quantify emissions of other air pollutants or of water pollutants from the two paths. It is likely that for most pollutants categories, emissions from the Alternative path will be lower than from the BAU path as a result of, for example, less oil refining activity, more limited use of liquid petroleum fuels, and more rapid phase-out of older steam-cycle electricity generation in the former path. Emissions of oily hydrocarbons to the marine environment should also go down in the Alternative case as a result of decreased crude oil imports and (possible) decreased shipping of petroleum products. Additional factors likely to contribute to lower hydrocarbon emissions in the Alternative path are decreased use of motor fuels and lubricating oils (due to improvements in passenger vehicles), which should markedly decrease the amount of oily hydrocarbons reaching the ocean in urban runoff.
- **Solid wastes**—Most of the solid wastes produced in the energy sector are from combustion of coal. Coal combustion produces ash ("fly ash", collected by particulate control devices, and "bottom ash", which remains after coal is burned), and additional wastes are produced by the operation of scrubbers that remove sulfur oxides from the exhaust gas stream of industrial and utility boilers. Lacking, at present, good information on the ash and sulfur contents of coals used in Japan, we have not attempted quantitative estimated of solid wastes from coal combustion for the two paths. Assuming, however, that solid waste production per unit of coal consumption will be similar in the two paths, one would expect that solid waste production in the Alternative path, by 2020, would be roughly half of that in the BAU path. To the extent that sulfur oxide emissions control is more stringent in the Alternative path than in the BAU path—thus producing more scrubber sludge—Alternative path emissions may constitute a larger fraction of BAU emissions.
- **Nuclear wastes**—Given that limited changes in nuclear technology are postulated for the nuclear power sector under either of the two paths considered, the production of nuclear wastes will likely scale (for the most part) with nuclear electricity generation. Based on the estimates of nuclear generation described above, annual nuclear waste generation will be about 8 percent lower in the Alternative path in 2020, and about 17 percent lower in 2020. If one were to integrate, for each path, the total nuclear wastes and spent fuel generated between 1995 and 2020, the difference between the two paths would probably be less than 10 percent. Under the Alternative path, measures to minimize the handling and transport of radioactive materials would probably translate into on-site (that is, at the power plant site) indefinite storage of spent nuclear fuel, using technologies such as "dry cask storage"[gggg].

[gggg] Dry cask storage as an option for nuclear waste stabilization in Northeast Asia is reviewed and evaluated in Von Hippel, D. and P. Hayes (1998), "Two Scenarios of Nuclear Power and Nuclear Waste Production in Northeast Asia" forthcoming in the special issue of the Pacific and Asian Journal of Energy on the future of nuclear power in Asia.

- **Ecosystem and Aesthetic impacts—**Ecosystem and aesthetic impacts under the Alternative path are likely to be somewhat lower than under the BAU path in that more care is taken to control pollution, traffic reduction measures are undertaken that may reduce the need for new roads, fewer large power plants, including nuclear plants, will be built, and marine tanker traffic will be somewhat reduced. On the other hand, large gas pipeline and LNG projects will be required in both scenarios, and the Alternative scenario includes large-scale deployment of wind and solar generation, which may (for some installations and for some people) have objectionable aesthetic impacts, as well as probably minor ecosystem impacts.
- **Exposure to Environmental Risk—**To the extent that the Alternative path results in reduced greenhouse gas, acid gas, and local air pollutant emissions, Japan's exposure to environmental risks will be reduced relative to the BAU path. Of course, for global and regional problems, Japan will be able to affect only a portion of the potential environmental impacts through its own policies. Following the Alternative path, however, will help to demonstrate to the countries of the region and the world that Japan is abiding by its international commitments to reduce its greenhouse gas emissions. Following the Alternative path will also help to provide Japan with additional technological wherewithal to be able to assist other countries in meeting their own greenhouse gas and acid gas emissions reduction goals. The Alternative path provides more modular and dispersed technologies (such as cogeneration, wind power, and solar power) in contrast to a continued reliance on larger, more centralized in the BAU path. The smaller, more dispersed nature of (particularly) electricity generation under the Alternative path, as well as the greater diversity of resources used, will likely make the Alternative path more resilient to major natural disasters such as earthquakes and severe storms.

7.3.5. Social and Cultural dimension

The degree to which one energy path or another is superior with respect to avoidance of the risk of social or cultural conflict over energy systems is, to say the least, difficult to determine. On one hand, one could argue that the reduction in the need for major generation facilities, including nuclear facilities, in the Alternative path suggests that the risks of social conflict over those facilities will be reduced. On the other hand, achieving the energy efficiency targets in the Alternative path may require a degree of marketplace coercion that, particularly in this era of "deregulation" and "restructuring" of markets, will lead to social dissatisfaction. In either path, it seems clear that many Japanese industries and entrenched constituencies, from oil refiners to smaller gas companies to auto-makers to government agencies, will undergo various degrees of dislocation. Although dislocations may well be somewhat more severe under the Alternative path, they are probably unavoidable in any future. The measures proposed in section 6.5.7—including measures to allow consumers more of a say in how energy infrastructure is developed, increasing transparency in energy planning, reducing the scale of energy facilities, and public education on energy and environmental matters—can all help to reduce the risk of social and cultural conflict over energy systems by giving people a sense of "ownership" in key energy decisions. Reduction of handling and transport of nuclear waste, as described above, will also help to reduce the risks of social conflicts over the handling of nuclear materials.

As one measure of the response of the two paths to cultural risk, we postulate a minor nuclear accident, as described in Section 6.6, that sufficiently erodes public confidence that all BWR-type nuclear reactors are ordered shut down at once as of 2010. The extent of the resulting electricity shortfalls in each path serves as an indicator of the difficulty in replacing the lost capacity. The absolute and relative shortfall in electricity supply resulting from the closure of the BWR fleet is less in the BAU path than in the Alternative path. This is likely because the Alternative path includes relatively more generating capacity that operates at less-than-baseload capacity factors (solar, wind, and cogenerated capacity, for example), so the loss of the baseload nuclear plants results in a greater electricity shortfall. Figuring out which path could recover most easily and with the least economic dislocation from the loss of the BWRs is a difficult and detailed proposition that is beyond the scope of this report. One possibility, however, in the Alternative scenario, is that much of the lost BWR capacity could be replaced at relatively short notice by bringing retired/mothballed coal-, gas-, and oil-fired capacity back on line, as has been done in the Japanese oil refining industry in recent years. This option—bringing back retired fossil-fueled capacity to substitute for the loss of the nuclear power—does not exist in the BAU path.

7.3.6. Military/Security dimension

Even in the absence of specific policies to reduce energy-related military and security risks, the exposure to such risks in the Alternative path will be somewhat less than in the BAU path simply due to 1) the reduced volume of crude oil and oil products coming in and out of the country, and 2) the somewhat reduced number of nuclear facilities and irradiated fuel that needs to be safeguarded. This security advantage for the Alternative path, however, is not overwhelming. The policies described in Section 6.5.8 of this report, including confidence building between nations of the region on energy and environmental issues, may do more, in the long run, to reduce potential military conflicts between the nations of the region than the increases in military and security measures that are a part of the BAU scenario (Section 6.4.8).

Spending on energy-related security arrangements in the Alternative case would likely be less than in the BAU case, in part due to the somewhat reduced flows of oil and nuclear materials, and in part due to a more cooperative regional political climate that flows from greater cooperation between nations on energy and environmental matters.

7.4. Path Comparison Overview: Matrix of Path Attributes by Energy Security Dimension

The results of the path analyses compiled above are summarized in Table 7-7 in order to provide a side-by-side comparison of the two candidate paths.

Table 7-7: Energy Security Comparison: BAU versus Alternative Paths

Dimension of Energy Security	**Attributes**	**BAU Path Result**	**Alternative Path Result**
Energy Supply	Total Primary Energy	2010: 26.2 EJ[hhhh]; 2020: 28.7 EJ	2010: 22.0 EJ; 2020: 28.7 PJ
	Fraction of Primary Energy as Imports	2020: 96% of fuel use	2020: 85% of fuel use
	Diversification Index (by fuel type, primary energy)	2010: 0.254 2020: 0.240	2010: 0.262; 2020: 0.230, 0.213 and 0.175 with separate accounting for pipeline gas, energy efficiency
	Diversification Index (by supplier, key fuel types)		Not quantified, but probably lower
	Stocks as a fraction of imports (key fuels)	Oil: 150 days stocks in 1995 lasts for 110 days in 2020	Oil: 150 days stocks in 1995 lasts for 187 days in 2020
Economic	Total Energy System Internal Costs		27 Trillion Yen (net present value) less than BAU path over 1990 to 2020
	Total Fuel Costs		32 Trillion Yen (net present value) less than BAU path over 1990 to 2020
	Import Fuel Costs		About the same as total fuel costs
	Economic Impact of Fuel Price Increase (as fraction of GNP)	In 2015, energy resource costs about 1% of GDP more than in Alternative path	Impact of 2010 oil price rise to 4,725 Yen per bbl about 27 trillion Yen NPV less than BAU path, 1990 to 2020.
Technological	Diversification Indices for key industries by technology type	For electricity generation: 2010: 0.166 2020: 0.138	For electricity generation: 2010: 0.153 2020: 0.105
	Diversity of R&D Spending		Probably Higher
	Reliance on Proven Technologies	Higher	
	Technological Adaptability		Probably Higher

[hhhh] One Exajoule, or EJ is equal to one billion gigajoules, or 10^{18} Joules.

Table 7-7 (cont.): Energy Security Comparison: BAU versus Alternative Paths

Dimension of Energy Security	**Attributes**	**BAU Path Result**	**Alternative Path Result**
Environmental	GHG emissions	In 2020: 1,600 Mte CO_2, 300 kte CH_4, 120 kte N_2O	In 2020: 1,000 Mte CO_2, 310 kte CH_4, 82 kte N_2O
	Acid gas emissions	In 2020: 2.0 Mte SO_x, 5.2 Mte NO_x	In 2020: 1.1 Mte SO_x, 3.2 Mte NO_x
	Local Air Pollutants	In 2020: 3.8 Mte CO, 1.1 Mte Hydrocarbons, 0.94 Mte Particulates	In 2020: 2.8 Mte CO, 0.55 Mte Hydrocarbons, 0.54 Mte Particulates
	Other air and water pollutants (including marine oil pollution)		Somewhat lower to substantially lower, depending on pollutant and pollutant source
	Solid Wastes (tonnes bottom ash, fly ash, scrubber sludge)		Likely somewhat lower (depends on fuel sulfur, ash contents, degree of scrubbing)
	Nuclear waste (tonnes or Curies, by type)		Somewhat (~5-10 percent over 1990 to 2020) lower; on-site spent fuel isolation means less waste transport
	Ecosystem and Aesthetic Impacts	More large-infrastructure-related impacts	More indigenous-energy related aesthetic impacts; less ecosystem impacts due to pollutants
	Exposure to Environmental Risk		Lower
Social and Cultural	Exposure to Risk of Social or Cultural Conflict over energy systems		Likely lower overall, but may require more social and cultural adjustment
Military/Security	Exposure to Military/ Security Risks		Likely somewhat lower
	Relative level of spending on energy-related security arrangements		Likely somewhat lower

7.5. Implications of the analysis for the choice of energy security measures and energy paths

The side-by-side comparison shown in Table 7-7 indicates that for most dimensions of energy security, the Alternative path is likely to be preferable to the Business-as-usual path. Although this conclusion must, of course, be tempered by consideration of the many uncertainties in the analysis, the fact that the Alternative path is somewhat to significantly better across virtually the full range of energy security dimensions (and the attributes that we have chosen as measures of energy security), provides some assurance that the overall result of the analysis is, indeed, robust. The energy security measures incorporated in the Alternative path, ranging from accelerated deployment of energy-efficiency technologies to greater transparency in energy planning, appear to be able to enhance energy efficiency, as we have broadly defined it, in multiple dimensions.

What the analysis presented above does not clearly reflect, however, is the degree of difficulty of achieving the Alternative energy path. Although the technologies used in the Alternative path could, in all likelihood, be available on the time scale the are called for, achieving the penetration required for, for example, energy-efficiency measures and renewable electricity options, will require an exercise of political will above and beyond purely market economics. Changing the focus of Japanese R&D spending to enable the Alternative path will require a similar exercise of political will, and will run counter to powerful entrenched constituencies. Some of the energy security measures incorporated in the Alternative path will call for changes in the way that the Japanese economy and, indeed, the Japanese society operate, and as a result will be difficult to implement. On one hand, Japan has a history of energy policy intervention in the market that would seem to enhance the probability of policies that could help bring about an energy future similar to the Alternative path. On the other hand, recent trends toward deregulation and liberalization of energy markets in Japan seem to run counter to many of the requirements of the Alternative path.

Another clear conclusion of the paths analysis is that if our estimate of energy use (and attendant carbon dioxide emissions) under the BAU path are near the mark, Japan cannot hope to meet its obligations under the terms of agreements made at the Third Conference of Parties (COP3) of the Framework Convention on Climate Change without either A) pursuing an energy path that is at least similar in application of energy-efficiency (and/or other non-carbon-emitting options) to the Alternative path, B) purchasing substantial carbon offsets from another country (Russia has been mentioned as a possibility), or C) a combination of A) and B). The other option for Japan to meet the targets of COP3, severe economic stagnation, is unlikely to be a chosen as a basis for planning.

A cynical reader of this document would likely point out that the comparison we have set up is unlikely; that the BAU path represents a “straw man” (an opponent of dubious quality) and the Alternative path is unlikely to come to fruition. This observation is, to a certain extent, correct. Although we feel that both the BAU path (given recent trends) and the Alternative path (given the technological possibilities) are possible, we have certainly chosen the two paths in such as way as to allow a clear distinction between path results. It should be remembered, however, that a major goal of the PARES project has been to begin the development of a new framework for energy security analysis, and that the principle goal of the energy paths analysis has been to provide an illustrative application of the draft analytical framework.

7.6. Potential Effects of Path “Variants” on Analytical Results

In a truly thorough analysis of the energy security impacts of alternative energy paths, one would examine a much wider range of paths than we have been able to look at in this report. Although the BAU and Alternative paths are at least close to opposite ends of the spectrum of medium-term possibilities for changes in Japan’s energy system, there are an infinite number of other possible paths. Below we attempt to briefly explore several “What if” questions related to the impacts of changes in path assumptions (path variants) on our analytical results.

- **What if the Japanese economy is not as robust as predicted?** If the Japanese economy does not perform to the levels assumed in the two paths, the need for energy services will (presumably) decrease, particularly, one would guess, in the Commercial and Services sector. A reduced need for energy services under both paths would mean that absolute differences between the two plans, in attributes such as primary energy use, fuel costs, and environmental emissions, would decline. The qualitative advantages of the Alternative path over the BAU path would, however, remain.
- **What if the costs of technologies in the Alternative path are higher than assumed?** The costs that we assumed for demand and supply-side measures in the Alternative path would have to be very significantly (two- to three-fold) higher to displace the fuel cost savings in the Alternative path.
- **What if a higher discount rate is used?** A higher discount rate would result in somewhat lower cost-effectiveness (on a net present value basis) for the Alternative path. Additionally, a higher discount rate would translate into a higher interest rate for demand- and supply-side investments, which would cause the costs in the Alternative path to rise somewhat more than in the BAU path (which relies, for the most part, on lower-cost, proven technologies). Again, a significant increase in costs would be necessary to offset the fuel cost savings indicated in the Alternative path.
- **What if BAU technology improvement is greater than expected?** Improved energy efficiency in the BAU case could yield a smaller difference between the two paths in many attributes, but would also likely result in lower net costs, for demand and supply infrastructure, in the Alternative path.
- **What if market liberalization runs its course, and the political will to impose (for example) energy taxes or provide energy-efficiency subsidies is not forthcoming?** Market liberalization will result in lower consumer prices for many energy commodities in Japan, which will reduce the incentive to invest in energy-efficiency and renewable energy technologies, as well as in expensive conventional technologies, such as nuclear power. The combination of market liberalization and low energy prices will make the Alternative path harder to bring to fruition. Possible countervailing factors are energy-efficiency improvements undertaken in order to improve commercial and industrial productivity or environmental performance (waste reduction), or policies implemented specifically to meet environmental goals.

8. Conclusion and Areas for Further Work

In the first phase of the Pacific Asia Regional Energy Security Project, as noted in Chapter 1 of this report, the overall goals have been to:

- Prepare a consensus working definition of "energy security",
- Develop an analytical framework, using different types of tools, for evaluating the energy security dimensions of different choices in energy sector development,
- Prepare quantitative and qualitative descriptions of two different short-to-medium range energy "paths" for Japan (1995 to 2020),
- Evaluate the energy paths against a suite of energy security criteria using the analytical framework, and
- Review the results for applicability to other countries of the region.

The PARES Working Group's progress in achieving the first four of these goals is detailed in earlier chapters of this report, and is summarized below. Also provided in the text that follows are our thoughts as to how the type of work described in this report might be applied in other countries of Northeast Asia (and elsewhere), as well as on a regional level.

The work described in this report has been informed by work done and opinions expressed by experts from both the United States and Japan. It is hoped that additional phases of work on the PARES project will continue what must be regarded as an ongoing, patient process of building connections and understanding between experts in the two countries, as well as with experts from other countries in Northeast Asia (and beyond).

8.1. Project Achievements

In Phase one of the PARES project to date, project participants have:

1. Reviewed the history of energy policy and of the concept of energy security in Japan, as well as the evolution of Japan's energy system. Commissioned papers (as provided in Attachments to this report) also explored aspects of environmental security, the role of energy efficiency and renewable energy in energy security, and oil supply security. Several papers (see Attachment Set C) focus on the future of nuclear power, and the role of nuclear power and nuclear fuel cycles in with regard to energy security in Japan and elsewhere[iiii].
2. Grappled with answering the question "What does energy security really mean, in a functional sense, in the late 1990s and beyond?". The conclusion reached was that energy security, as a concept, should extend beyond the traditional confines of assuring physical supplies of fuel (and the economic implications thereof), to encompass (at least) six different dimensions. A nation-state is energy

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[iiii] The complex and potentially divisive topic of nuclear power, and its role in energy security, has largely been skirted in this Report in order to focus on methodological issues of energy security. It is likely that a separate Working Group will be formed specifically to take a closer look at the role of nuclear power in enhancing (or decreasing) energy security.

secure to the degree that fuel and energy services are available to ensure: a) survival of the nation, b) protection of national welfare, and c) minimization of risks associated with supply and use of fuel and energy services. The dimensions of energy security within each of these three the objectives of energy security which national energy policies must address should be measured, include energy supply-related, economic, technological, environmental, social and cultural, and military/security-related dimensions. *And*, energy policies must address the domestic and international (regional and global) implications of each of these dimensions. Thus, national energy policies should be evaluated against each of the three basic objectives as manifested in the domestic and international implications of each dimension. What distinguishes the PARES energy security definition is its emphasis on the imperative to consider extra-territorial implications of the provision of energy and energy services while recognizing the complexity of actualizing (and measuring) national energy security.

3. Described the evolution and current state of the concept of "Environmental Security" and evaluated the linkages between Environmental Security and energy security.
4. Considered the existing analytical tools for gauging whether a particular energy path—that is, whether a particular set of energy policies (explicit or implicit)—provides a higher level of energy security, as broadly defined, than a different energy path.
5. Building on existing work by project participants and others, proposed an analytical framework for evaluating the energy security costs and benefits of different candidate energy paths.
6. Devised two illustrative "energy paths", covering the period from 1995 through 2020 for Japan. The "Business-as-Usual" path primarily extrapolates recent trends in Japanese energy use, technologies, and policies, while the "Alternative" path includes aggressive implementation of energy efficiency, renewable energy for electricity production, fuel switching to natural gas, and a host of other policies designed to enhance the flexibility of the energy system and cooperation on energy and environmental issues within and outside of Northeast Asia. In both cases, the paths are demand-driven, and contain sufficient detail to both A) assess how needs for energy services are being met at the end-use level, and B) to ascribe specific costs and environmental emissions to major components (demand, supply and fuel resources) of the energy system.
7. Tested the two candidate energy paths within the proposed analytical framework by evaluating and comparing, quantitatively and qualitatively, a set of different "energy security attributes" for each of the dimensions of energy security identified.
8. Reviewed the results of the path evaluation for lessons about the desirability of different approaches to providing energy services in Japan, by asking which candidate plan (if either) enjoys a clear advantage across energy security dimensions relative to the other.

The analytical framework that we have developed is straightforward in its application, but requires (as we believe it should) careful and consideration—both objective and subjective—in order to evaluate many of the energy security attributes. Application of the framework also requires that the candidate energy paths be described in sufficient detail as to allow clear evaluation of attributes.

In our analysis of the two candidate energy paths for Japan, we conclude that the Alternative path provides, for most energy security attributes, somewhat to significantly better energy security performance than the BAU path. The Alternative path, however, will undoubtedly require a significantly greater application of political will to bring it to reality.

8.2. Work to Be Done/Major Uncertainties in Japan Energy Security Analysis

Of necessity, the BAU and Alternative paths as developed in Chapter 6 and evaluated in Chapter 7 contain a host of estimates and approximations. Improving these estimates will help in making the conclusions of the path comparison more robust. Among the many areas in which additional data and/or refined information from Japan and elsewhere would assist in elaborating the energy paths are (in no particular order):

- Additional Japan-specific estimates of the costs, effectiveness, and potential applicability of energy efficiency and fuel-switching measures and technologies, particularly those now under development in Japan.
- Japan-specific environmental emission factors for key technologies, and emission factors for emerging technologies such as hybrid vehicles, condensing furnaces, and fuel cells.
- Japan-specific costs, including estimates of future costs, for key technologies and infrastructure, including technologies for electricity generation, oil refining, and LNG/natural gas imports.
- Better-informed and elaborated estimates of how the Japanese oil refining and LNG import industries will adjust capacity in the future in response to changing domestic demand and international market conditions.
- Refined figures for current fuel costs, and improved, Japan-based estimates of future costs of domestic and imported fuels.
- Additional data on energy end-uses, particularly in the services/commercial/public sector.
- Data on the extent of solar, wind power, and biomass resources in Japan.

8.3. Summary of Major Analytical Approach

The major analytical approach used to evaluate energy security in this report is a variant of “Multiple Attribute Analysis” or “Trade-off Analysis”, and is an adaptation of a method proposed by Dr. Hossein Razavi (see Attachment Set A). Broadly, the analytical approach includes the following steps (as noted in Chapter 5):

- Define objective and subjective measures (or “attributes”) of energy security.
- Develop candidate energy paths (and/or longer-term scenarios).
- Test the relative performance of paths/scenarios by evaluating measures of energy security. This step includes the application of indices of supply or technological diversity, a concept elaborated by Dr. Thomas Neff (see Attachment Set A).
- Incorporation of the elements of risk from unforeseen events (including accidents, natural disasters, war, and other policy-relevant risks).
- Comparison of path and/or scenario results—including quantitative and qualitative comparisons.
- Elimination of energy paths that lead to clearly sub-optimal or unacceptable results.

8.4. Summary of Major Results of Paths Analysis

Our evaluation of the two illustrative energy paths for Japan yielded the following results, grouped by the six dimensions of energy security identified above:

- **Energy Supply**: By the year 2020, the annual amount of primary energy required by the Japanese economy under the Alternative path is about 75 percent of that required in the BAU path. In both cases, imports still dominate energy supply by 2020, but about domestic resources supply about 15 percent of needs in the Alternative path, versus about 4 percent in the BAU path. The diversity of energy supply, as measured using a diversification index, is similar in both paths in 2010, but is somewhat greater (lower index value) in 2020 for the Alternative path than for the BAU path.
- **Economic**: The net present value cost difference between the two paths between 1990 and 2020 is estimated at 27 trillion (1990) Yen, with the Alternative path costing less. Although costs for end-use equipment and fuel transformation infrastructure is higher in the Alternative path, the fuel savings in the Alternative path, relative to the BAU path, far outweigh the extra costs. In an analysis of the sensitivity of path costs to an sharp and sustained rise in oil prices, the economic impact on the Alternative path was considerably less than on the BAU path.
- **Technological**: The Alternative path would likely yield greater technological diversity (in, for example, electricity generation and other key energy-related sectors), and would also imply a greater diversity of R&D spending. The BAU path, on the other hand, reduces technological risk of some kinds through reliance primarily on proven technologies.
- **Environmental**: The Alternative path yields sharply lower yearly emissions of carbon dioxide, in 2010 and 2020, than the BAU path. Annual emissions of other greenhouse gases, acid gases, and local air pollutants are also expected to be at most similar to those in the BAU path, and in some cases may be nearly 50 percent lower by 2020. Emissions of solid and liquid wastes are also likely to be somewhat lower under the Alternative path, as would be production of nuclear wastes. Both the Alternative and BAU paths are likely to cause ecosystem and aesthetic impacts, both those impacts will be sufficiently different in type that it is difficult to say which path is preferable on this score. The Alternative path is likely to reduce exposure to risk of environmental catastrophe, although the magnitude of risk reduction may be small by 2020.
- **Social and Cultural**: The Alternative path helps to reduce risk of social discontent over energy issues by increasing citizen participation in energy decision-making, as well as the transparency of decision-making. On the other hand, the Alternative path implies changes in the way that energy is supplied in Japan that may cause some economic dislocation, and possibly, social and/or cultural conflict. Our test of the sensitivity of both paths to an incident where (mostly) social pressure causes the effectively instant closure (in 2010) of a majority of Japan's nuclear reactors indicates that a substantial electricity deficit would accrue in both cases, but in the Alternative case, enough "mothballed" fossil-fueled capacity might exist to make the transition easier.
- **Military/Security**: The BAU path, with somewhat greater flows of nuclear material to safeguard and somewhat greater flows of crude oil and petroleum products to look after, would present a somewhat greater degree of military-related security risk—and associated cost—than would the Alternative path. Increased bilateral and multi-lateral confidence-building exercises and cooperation in energy and environmental matters in the Northeast Asia region also increase the likelihood that the Alternative path will be preferable from a military-security point of view.

Overall, the Alternative path appears to have advantages over the BAU path in many of the dimensions of energy security as we have defined it here. As such, the Alternative path would appear to be a robust choice, in this analytical illustration, as an energy path for Japan, over the BAU path. Of course, the Alternative and BAU paths are hardly the only two possibilities for the evolution of the Japanese energy system through 2020, but our analysis indicates that the core measures of the Alternative path—an aggressive commitment to energy efficiency, renewable energy, and a reduction of environmental impacts, as well as transparency in energy planning, and regional cooperation in energy and environmental matters—will be key to helping Japan improve its energy security, in the broad sense that we have defined the term here.

8.5. Ramifications of Results for Japanese and Pacific Asia Energy Policy and Energy Futures

If, as our results suggest, energy efficiency, renewable energy, environmental protection, and changes in the way that Japan accomplishes its energy planning and interacts with its neighbors will help to enhance national energy security, how will these changes be brought about? The detailed exploration of policy instruments to direct the energy sector along or toward particular paths is well beyond the scope of this report, and has been taken up by many authors. Obvious policies that come to mind include energy or carbon taxes, subsidies for specific industries/technologies, the ending of subsidies for other industries/technologies, “green marketing” to bring the environmental cost of purchases into focus for consumers, strict environmental regulations, energy codes for houses, appliances, vehicles, and other energy-using or energy-transforming infrastructure, and a host of other options. Many of these sorts of policies, though not specifically in the energy arena, have been common in Japan, and thus may be acceptable if “packaged” appropriately. Running counter to the acceptability of such measures is the trend toward deregulation and open global markets, although work on how to integrate “sustainability” criteria into “free” markets is progressing.

We would hesitate to generalize the results presented in this report—based, after all, on paths that are meant primarily to be illustrative—to other countries in Northeast Asia. We would note, however, that many of the differences in energy security attributes between the two paths shown are large. Given that the paths cover both a relatively limited time span and, as they apply to Japan, provide for a relatively modest growth in the need for energy services, we would speculate that the differences between similar energy paths for a country like (to pick a non-random example) China—or even North Korea—would be truly monumental. If we are right in this speculation, the need for considered, transparent, multi-dimensional analysis of energy security issues and future energy paths in the countries of Northeast Asia is more than evident.

8.6. Applicability of Analytical Methods and Case Study Results for Other Nations

Although energy security, as traditionally defined, has long been a focus of Japanese policy-making, energy security, as more broadly defined in this report, is equally applicable to, and increasingly important for, the other countries of Northeast Asia. The importance of energy security considerations in the region will increase particularly as growing economies place strains on local and regional resources—energy, environmental and otherwise.

The structure that we propose in this report for analysis of the energy security attributes of different paths of energy system development is, theoretically, applicable to any national or regional situation. The structure can be easily modified to add attributes that are important to the region under study (or to delete attributes that do not matter), and can accommodate that results of a host of local analytical resources (for example, national energy models), so long as the inputs to and outputs of local models maintain sufficient transparency to be easily understood by reviewers.

Application of an energy security evaluation framework on both national and regional levels could provide interesting insights. It is possible, for example, that an analysis of potential energy paths on the regional level will suggest a set of robust policy directions that are similar to those suggested by the results of country-level energy security studies. The opposite, however, is also possible: strategies for enhancing energy security on the country level could, when considered in their regional context, be sub-optimal with respect to regional energy security. In both cases the major importance of the evaluation framework, however, is to provide a structured, documented, relatively easy-to-understand approach to thinking about the broader impacts of energy system issues.

Additional Phases of the PARES project could, we feel, usefully focus on pursuing energy paths analyses of the type that we have attempted here in each of the countries of the region, as well as at a regional level. At a minimum, this type of activity should increase understanding between the countries of the region and serve as a confidence-building exercise. The results of the analyses, taken in aggregate, may well suggest robust policy directions that will clearly enhance energy security in the region. Timely and well-designed dissemination of analytical results to regional policy-makers and the public would be the next step in moving the identified energy security policies toward implementation.

8.7. Topics for Further Research

The work of Phase I of the PARES project in the development of analytical methods to evaluate energy security is no more than a beginning in the effort to explore meaningful and effective ways of looking at energy security tradeoffs among different energy paths. Among the methodological issues that could be further elaborated are:

- Developing better ways to summarize and visualize the multiple energy security dimensions and attributes of different energy paths. Here the goal would be to refine the presentation of multi-dimensional results so that the results can be easily understood and interpreted by policymakers.
- Developing data sets that allow correlations between the amounts and prices of fuel supplied by different nations (or regions) to be incorporated into supply diversification indices.
- Finding a better way to capture and summarize economic interactions within candidate energy paths, short of full-fledged dynamic input-output analysis. Economic interactions include the impacts of fuel price changes (including taxes) on fuel use and energy-related investment, and the impact on certain industries when energy policy-driven technological changes are implemented.
- Identifying more effective ways of evaluating the energy security impacts of risks (and risk-avoidance policies) of different types.
- Exploring analytical methods for evaluating the military security impacts and costs of different energy paths.

- Exploring how more extensive use of the scenario building process described in Chapter 7 can be integrated into the analytical framework proposed here.

The above, of course, is at best only a partial indication of the additional energy security topics that could be addressed.

9. Endnotes

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